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Benefit-Cost Results. This report examines five options to improve seats in transport category airplanes operating under 14 CFR part 121.

- **Option 1: Ongoing surveillance, no regulatory action.** This option would not require full or partial 16g seats* in new or in-service airplanes, but could include continued seat testing programs as well as ongoing surveillance of the industry to monitor installed seat types.

- **Option 2: Require full 16g seats in newly manufactured airplanes by 2005.** Require that all newly manufactured transport category airplanes operating under 14 CFR part 121 comply with the requirements of 14 CFR §25.562(a), (b), and (c).

- **Option 3: Require full 16g seats in newly manufactured airplanes by 2005 and partial 16g seats in all in-service airplanes operating under part 121 by 2007.** In addition to the requirements of Option 2, this option would require that seats in in-service airplanes (that is, airplanes manufactured before 2005) meet 14 CFR §25.562(a), (b), and (c) excluding head injury criteria.

- **Option 4: Require full 16g seats in newly manufactured airplanes by 2005 and discretionary replacement with partial 16g seats by 2007 for other in-service part 121 airplanes.** In addition to the requirements of Option 2, this option would require that when seats in in-service airplanes are replaced (at the discretion of the operator/owner) they must be replaced with seats that meet 14 CFR §25.562(a), (b), and (c) excluding head injury criteria.

- **Option 5: Require full 16g seats in newly manufactured airplanes by 2005 and discretionary replacement with full 16g seats by 2007 for other in-service part 121 airplanes.** In addition to the requirements of Option 2, this option would require that when seats in in-service airplanes are replaced (at the discretion of the operator/owner) they must be replaced with seats that meet 14 CFR §25.562(a), (b), and (c).

The main findings of this report:

- Considering only passengers, if regulatory action is taken, then the most effective option (in terms of benefit-cost) is Option 5—discretionary replacement for passenger seats.

- Option 5 also yields the greatest lifecycle safety benefits measured in terms of fatalities and net serious injuries averted.

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* "Full 16g" refers to seat installations that comply with 14 CFR §25.562 (a), (b), and (c). "Partial 16g" refers to seat installations that meet 16g structural loading requirements but have not been certificated as compliant with some or all occupant injury requirements in 14 CFR §25.562 (c).

- If Option 5 is implemented for passenger seats, there are three possible courses of action for flight attendant seats: 1) no requirement for flight attendant seats, 2) discretionary replacement for flight attendant seats (independent of whether passenger seats are replaced), 3) require flight attendant seat replacement at the time of passenger seat replacement (i.e., flight attendant seats must be replaced if passenger seats are replaced). Adding a flight attendant seat requirement to the passenger seat replacement reduces benefit-cost. This follows since flight attendant seats are typically not replaced during the life of an airplane.

- Under the assumption that both passenger and flight attendant seats are subject to replacement, Option 2 is the best option in terms of benefit-cost. Although Option 5 is still optimal in terms of total fatalities and net serious injuries averted.

Table ES-1 shows the estimated number of fatalities and serious injuries averted under each option. *The safety benefits associated with each option are adjusted to account for voluntary installation of full and partial 16g seats.*

Table ES-1: Projected Number of Lifecycle Fatalities and Serious Injuries Averted by Option

Option	Fatalities Avoided	Serious Injuries Avoided
1	0.0	0.0
2	34.2	39.7
3	95.3	110.7
4	65.4	76.0
5	114.4	132.9

Tables ES-2a, b, and c show the costs and benefits of each option expressed in millions of dollars.

Table ES-2a: Projected Lifecycle Costs and Benefits, Passenger Seats
Millions of Undiscounted and Discounted Dollars

	Costs		Benefits		B/C
	Undisc.	Discount	Undisc.	Discount	Discount
Reg. Eval. (Hi)	$667.5	$424.4	NA	NA	NA
Reg. Eval. (Lo)	$667.5	$424.4	NA	NA	NA
Option 1	$0.0	$0.0	$0.0	$0.0	NA
Option 2	$70.7	$29.6	$109.8	$34.4	1.164
Option 3	$697.7	$483.6	$306.4	$122.6	0.254
Option 4	$133.7	$58.3	$210.2	$68.8	1.179
Option 5	$232.9	$101.9	$367.8	$120.8	1.185

Table ES-2b: Projected Lifecycle Costs and Benefits, Flight Attendant Seats
Millions of Undiscounted and Discounted Dollars

	Costs		Benefits		B/C
	Undisc.	Discount	Undisc.	Discount	Discount
Reg. Eval. (Hi)	$85.0	NA	NA	NA	NA
Reg. Eval. (Lo)	$85.0	NA	NA	NA	NA
Option 1	$0.0	$0.0	$0.0	$0.0	NA
Option 2	$12.0	$4.1	$2.2	$0.7	0.170
Option 3	$343.5	$185.9	$6.3	$2.5	0.013
Option 4	$274.9	$134.2	$4.3	$1.4	0.010
Option 5	$285.7	$138.9	$7.5	$2.5	0.018

Table ES-2c: Total Projected Lifecycle Costs and Benefits
Millions of Undiscounted and Discounted Dollars

	Costs		Benefits		B/C
	Then-Year	Discount	Then-Year	Discount	Discount
Reg. Eval. (Hi)	$752.6	$424.4	$1,230.0	$531.0	1.25
Reg. Eval. (Lo)	$752.6	$424.4	$679.0	$293.0	0.69
Option 1	$0.0	$0.0	$0.0	$0.0	NA
Option 2	$82.7	$33.7	$112.1	$35.1	1.042
Option 3	$1,041.3	$669.5	$312.6	$125.1	0.187
Option 4	$408.6	$192.5	$214.5	$70.2	0.365
Option 5	$518.6	$240.8	$375.3	$123.2	0.512

These results depend on several key assumptions. For example, it is plausible that, as a result of existing regulations and economic conditions, the distribution of seats in the part 121 transport category fleet will continue to migrate to full 16g and 16g compatibility without any additional future requirements. If casualty rates fall during the forecast period, then options 2, 3, 4, and 5 may represent unnecessary expenditures that yield little or no incremental life saving benefits. A discussion of the sensitivity of the results to changes in these and other assumptions is provided at the end of this report.

On the other hand, this analysis assumes that air carriers and seat manufacturers take no action to reduce costs given a new regulation. In fact, it is likely that affected agents will modify design and manufacturing practices to reduce costs—in particular, certification costs. This could be achieved, for example, by standardizing seat designs or creating families of seats.

Implementation Issues For Discretionary Replacement Options. Tables ES-1 and ES-2 describe in broad terms the forecasted effects of Options 1 through 5 on industry costs and safety risks. However the analysis does not consider implementation details such as: 1) the effects on small air carriers operating under 14 CFR part 121, 2) the effects on small seat manufacturers (if any), 3) possible industry action to circumvent the provisions of these options.

Small entity effects are beyond the scope of this study.[*] However, consideration was given to two circumvention problems:

1. Purchase of foreign (or other non-part 121) aircraft with non-TSO-127 seats.

2. Piecemeal replacement of non-TSO-127 seats to circumvent the intent of the proposed rule.

The analysis assumes that discretionary replacement options (Options 4 and 5) would only apply to 14 CFR part 121 air carriers. Therefore, if a U.S. air carrier purchased an airplane from a non-part 121 operator (for example, a foreign air carrier) in the future, that airplane would not be required to have 16g seats—until the seats were replaced under part 121 service.

Also, the analysis implicitly assumed that discretionary replacement would only apply in cases where an operator was replacing a substantial section of seats—not, for example, a single row of seats due to damage experienced in normal service. It is conceivable that operators may circumvent the intent of discretionary replacement by delaying replacement or replacing seats in a piecemeal fashion (similar to industry practice with respect to fire hardened interior materials).

The question, then, is how to preserve the advantages of a discretionary approach, but preclude less scrupulous operators from circumventing the requirement. One concept is to gradually phase in more restrictive requirements—that is, to make them less discretionary over time. For example:

Phase 1: Effective date through year five--no requirement for either newly manufactured or in-service aircraft.

Phase 2: Year five through year 10--all newly manufactured aircraft must have TSO-127 seats. For in-service aircraft if a section of seats is replaced, then it must be replaced with TSO-127 seats (discretionary replacement). BUT, the rule language will be drafted so that a limited number of seats can be replaced with non-TSO-127 seats (e.g. replacing broken seats).

Phase 3: Year 10 through year 17--For in-service aircraft ANY replacement of seats must be accomplished with TSO-127 seats--even if the replacement involves a single row of seats. This provision will preclude the possibility that operators can replace seats on a piecemeal basis to circumvent the rule. (E.g. if the operator argues that the row of seats in front of the replaced seats cause a compliance problem, then the row must be moved forward or must also be replaced.)

Also, this phase could include a provision that would require that all used aircraft purchased from non-part 121 operators (for example, foreign operators) must be retrofitted with full 16g seats before entering part 121 service.

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[*] If the FAA initiates rulemaking regarding 16g seats, the analysis of small entity impacts would be contained in the *Regulatory Flexibility Determination and Analysis*.

Phase 4: Year 17 on: All seats must be TSO-127 (drop-dead date).

Based on the current distribution of aircraft and seat types, the historical pattern of seat replacement (mean seat life of 14 years), and an assumed passenger airplane service life of 42 years, this analysis predicts that fleet-wide 16g replacement under Option 5 will occur at the end of year 17.

The four-phase implementation concept described above would have no effect on predicted costs or benefits, unless operators attempted to circumvent the provisions of Options 4 or 5 by delaying 16g seat replacement or acquiring non-part 121 aircraft. Otherwise, the concept is roughly neutral with respect to the cost benefit analysis.

I. Background

A. Policy Issues and Decision Factors

This report analyzes five options to improve seats in transport category airplanes operating under 14 CFR part 121:

- **Option 1: Ongoing surveillance, no regulatory action.** This option would not require full or partial 16g seats[1] in new or in-service airplanes, but could include ongoing surveillance of the industry to monitor installed seat types as well as continuing to test seats.

- **Option 2: Require full 16g seats in newly manufactured airplanes by 2005.** Require that all newly manufactured transport category airplanes operating under 14 CFR part 121 comply with the requirements of 14 CFR §25.562(a), (b), and (c).

- **Option 3: Require full 16g seats in newly manufactured airplanes by 2005 and partial 16g seats in all in-service airplanes operating under part 121 by 2007.** In addition to the requirements of Option 2, this option would require that seats in in-service airplanes (that is, airplanes manufactured before 2005) meet 14 CFR §25.562(a), (b), and (c) excluding head injury criteria.

- **Option 4: Require full 16g seats in newly manufactured airplanes by 2005 and discretionary replacement with partial 16g seats by 2007 for other in-service part 121 airplanes.** In addition to the requirements of Option 2, this option would require that when seats in in-service airplanes are replaced (at the discretion of the operator/owner) they must be replaced with seats that meet 14 CFR §25.562(a), (b), and (c) excluding head injury criteria.

- **Option 5: Require full 16g seats in newly manufactured airplanes by 2005 and discretionary replacement with full 16g seats by 2007 for other in-service part 121 airplanes.** In addition to the requirements of Option 2, this option would require that when seats in in-service airplanes are replaced (at the discretion of the operator/owner) they must be replaced with seats that meet 14 CFR §25.562(a), (b), and (c).

For each option, benefits and costs are computed separately for passenger seats and cabin attendant seats.

Each option is discussed in terms of four "decision factors":

[1] "Full 16g" refers to seat installations that comply with 14 CFR §25.562 (a), (b), and (c). "Partial 16g" refers to seat installations that meet 16g structural loading requirements but have not been certificated as compliant with some or all occupant injury requirements in 14 CFR §25.562 (c).

- **Factor 1:** What will the underlying rate of accidents, injuries, and fatalities be during the forecast period? (For example, even if the difference in performance between 16g seats and non-16g seats is very large, if the future accident rate is very low, a 16g-seat requirement may not be cost-beneficial.)

- **Factor 2:** How does each option affect the future distribution of seat types in the part 121 fleet? (For example, if industry trends are such that a given option will have very little effect on the future distribution of seat types, then a requirement based on that option may not be cost beneficial.)

- **Factor 3**: To what degree do different vintages of full 16g and partial 16g seats reduce the risks of injuries and fatalities? (For example, if there is little practical difference between full 16g seats and current generation, non-TSO-127 seats, then a requirement for full 16g seats may not be cost-beneficial.)

- **Factor 4:** What are the net costs of each option?

B. Report Organization

Throughout this report, transport category airplane seat installations are divided into three broad categories: 1) "Full 16g" seat installations are compliant with 14 CFR 25.562 (a), (b), and (c).[2] 2) "Partial 16g" seat installations are compliant with some of 14 CFR 25.562 (a), (b), and (c) but have not been tested to meet all occupant injury criteria.[3] 3) "9g" seat installations refer to older vintages of seats that meet 9g structural requirements only.

Section II explains the method used to estimate benefits, constructs baseline estimates of the population of affected airplanes, projects the distribution of part 121 seat types for the period 2000-2020 (assuming no future regulatory action), and forecasts future fatality and serious injury rates. Section III explains the methods used to estimate costs and constructs baseline cost estimates for passenger and flight attendant seats.

Sections IV, V, VI, VII and VIII estimate the costs and safety benefits of options 1, 2, 3, 4 and 5, respectively. Sensitivity analyses, describing how various decision factors (and, concomitantly, the benefit-cost results) are affected by changes in the underlying assumptions, are presented in Section IX.

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[2] In some cases, exemptions may apply to certain installations (e.g. pilot/co-pilot seats, flight deck floors).

[3] Note that this definition does not necessarily imply that the seat/installation cannot meet all the requirements of 14 CFR 25.562, only that there is no certification testing to demonstrate its compliance (or noncompliance).

II. Benefits Methodology and Baseline Risk Estimates

Baseline risk estimates are computed as follows:

- ***Construct an estimate of the future number of enplanements***.

- ***Construct a baseline estimate of the distribution of seat types.*** This analysis divides the projected population of seats into different groups (see the discussion below) depending on the date of aircraft manufacture and the projected date of seat replacement. The distribution of enplanements across seat groups is assumed to be proportional to the number of seats in each group. Replacement seats are assumed to be distributed according to the estimated proportion of full 16g, partial 16g, and 9g seat certification programs. For example, if 10% of seat certification programs are 9g, it is assumed approximately 10% of seats installed or replaced will be 9g.

- ***Forecast fatality and injury rates***. This analysis postulates that the projected rates of fatalities and injuries per enplanement during the forecast period are equal to the rates observed during the period 1984-1998 (U.S. 14 CFR part 121 fleet only). Key assumptions: 1) the rate is assumed to reflect a 9g baseline, 2) no improvements in historical fatality or injury rates are expected to occur during the forecast period, and 3) the risk reduction potential of 16g seats is not expected to improve (e.g., due to the introduction of additional cabin safety measures). *Example: Three-hundred-and-twenty-nine (329) injuries were recorded during 14 CFR part 121 operations during the study period (1984-1998—see Table II.3 of this document). In the same period, part 121 operators accumulated 7540.9 million enplanements. Therefore, the historical (and projected) rate of injuries is 329 ÷ 7540.9 = 0.0436 per million enplanements.*

- ***Estimate the reduction in fatalities and injuries during the study period (1984-1998)***. *Example: Based on the Cherry analysis (part 121 benefits based on worldwide fleet accident characteristics), the fleetwide use of full 16g seats would have averted 79 injuries (net) during the study period.*

- ***Estimate the percentage reduction in fatalities and injuries during the study period***. The number of fatalities averted due to 16g seats divided by the total number of fatalities during the study period yields an estimate of the percentage reduction in fatalities that would be achieved by requiring 16g seats. Similarly, the number of injuries averted due to 16g seats divided by the total number of injuries yields an estimate of the percentage reduction in injuries that would be achieved by requiring 16g seats. *Example: There were a total of 329 injuries during the study period (U.S. 14 CFR part 121). According to Cherry, 79 injuries could have been averted had 16g seats been installed in the part 121 fleet. Therefore, a 16g seat requirement could have averted 79/329 = 24% of serious injuries during the study period.*

- ***Determine adjustment factors for each seat group***. The degree to which a new seat reduces fatality and injury risks is a function of the vintage of seat it is replacing. As noted elsewhere in this study, however, the *Cherry Benefits Analysis* did not estimate the relative performance of full and partial 16g seats. Aircraft Certification Service engineers provided subjective estimates of the performance of seats in Groups I-V (see Figure 2 and the discussion in below). *Example: A Group V seat (full compliance with 14 CFR 25.562) has an effectiveness rating of 1.0. Therefore, this type of seat is expected to reduce injuries by 1.0 $\times$ 24% = 24% relative to a 9g seat. A Group II seat (i.e., does not meet occupant injury criteria) has an effectiveness rating of 0.1—10% of the effectiveness of a full 16g seat. Therefore, Group II seats are expected to reduce injuries by .1 $\times$ 24% = 2.4% relative to a 9g seat.*

- ***Forecast baseline fatality and injury rates***. Baseline estimates of the numbers of fatalities and injuries for the forecast period are obtained by combining: 1) the baseline (9g) fatality and injury rates, 2) the baseline distribution of seat types and enplanements, 3) the risk reduction potential of 16g seats, and 4) the adjustment factors.

- ***Forecast the effect of each option on the distribution of seats***. Potential benefits, then, reflect the degree to which any option alters the future distribution of seat types (relative to the projected baseline distribution). That is, the more the distribution shifts to full 16g and partial 16g seats, the lower the expected future rates of fatalities and injuries.

The following discussion uses the steps outlined above to derive baseline estimates of fatalities and injuries. The baseline estimates, then, are compared to fatality/injury estimates for each option.

A. Enplanement Forecast

Estimates of the number of future enplanements were derived from the *FAA Aerospace Forecasts, Fiscal Years 1999-2010*. The average annualized growth rate for the forecast period 2000-2010 was applied to years 2011-2020. The results of these calculations are shown in Table II.1.

Table II.1: Projected Enplanements for Affected U.S. Commercial Carriers[4]
(Millions)

2000	676.9
2001	695.8
2002	723.7
2003	753.2
2004	783.5
2005	815.0
2006	848.0
2007	882.4
2008	917.3
2009	953.4
2010	990.8
2011	1029.3
2012	1069.2
2013	1110.8
2014	1153.9
2015	1198.7
2016	1245.3
2017	1293.6
2018	1343.9
2019	1396.1
2020	1450.3

B. Baseline Seat Distribution Forecasts

1. Affected Airplanes

The current population of affected airplanes was estimated as follows:

- N-registered turbine powered aircraft;
- minus non-passenger carrying airplanes;
- minus non-part 121 airplanes;
- minus airplanes certificated before 1958;
- minus non-transport category airplanes (e.g. commuter category).

[4] Note: these enplanement projections reflect U.S. commercial air carriers, regional air carriers and commuter air carriers. In some cases, carriers may not operate aircraft that are subject to a 16g requirement (e.g., airplanes certificated under 14 CFR part 23 commuter requirements). Projections for the period 2000-2010 are taken from the FAA Aerospace Forecast. Projections for the period 2011-2020 are extrapolated from 2010 using the mean growth rate for 2000-2010. Source: Table 11, *FAA Aerospace Forecasts, Fiscal Years 1999-2010*.

An inventory of U.S. registered turbine powered airplanes was obtained from the FAA National Aviation Safety Data and Analysis Center (NASDAC) in October of 1999. This listing included registration number, owner, operator, manufacturer, model, sub-variant, date of manufacture, number of seats, and aircraft usage (e.g. cargo-only, passenger-only, military, etc.). The last two fields were used to identify non-passenger-carrying aircraft.

A list of part 121 and dual certificate part 121/135 operators was obtained from the FAA Flight Standards Service Regulatory Support Division (AFS-400) Aviation Information Website. The date of airplane certification was obtained from Type Certificate Data Sheets (TCDS--copies of which are available online in the FAA Aircraft Certification Service's Regulatory and Guidance Library). TCDS were also used to identify the certification basis of each airplane (i.e., which airplanes are subject to amendment 25-64, Emergency landing dynamic conditions), and to determine which airplane derivatives comply with some or all of 14 CFR §25.562.

Based on the TCDS, the following airplane models/variants comply with some provisions of 14 CFR §25.562 (i.e. are partial 16g).

- Airbus A319. Passenger seats only. (c)(5) and (6) do not apply.

- Boeing B717. Exception from (b)(2), (c) (5), and (6). Exception for (b)(2) for cockpit floor deformation only; compliance required for the passenger floor. Exception for HIC pilot/co-pilot seats, observer seat and front row passenger seats only; compliance required with row to row HIC requirements for all seating in addition to cabin attendant seats. Exception for leg injury criterion for pilot/co-pilot seats and observer seats only.

- Boeing B757-300. Passenger seats must meet 14 CFR §25.562 (a), (b) C(1)-(4), (7), and (8)

- Boeing B737-700, 800. Flight attendant seats must be qualified to TSO C127, dated March 30, 1992, or qualification to TSO C127a, and: a) Head Injury Criteria data collected and reported by TSO applicant is less than 1,000, and b) Femur Injury Criteria data collected and reported by TSO applicant is less than 2,250 pounds, and c) permanent deformation data collected and reported by TSO applicant are in compliance with the requirements of FAA Advisory Circular (AC) 25.562-1A. Passenger and crew seats in flight deck will comply with §25.562(a), (b), (c)(1)-(4), (7), and (8). In addition flight deck observer seats will comply with §25.562((c)(5)). Medical stretchers used to transport non-ambulatory occupants are not required to comply with §25.562.

- Boeing/McDonnell-Douglas MD-90-30. Passenger seats must comply with 14 CFR §25.562(b), (c)(2), (4), (7), and (8).

- Jetstream 41. Exemption number 5587 issued January 13, 1993, head impact criteria (25.562(c)(5)) for the three most forward passenger seats.

- Cessna Model 560 XL. Certification basis includes Amendment 25-64. Exceptions from §25.562(c)(5) and (6)

The certification basis for the following airplane types includes amendment 25-64 (i.e. these are full 16g compliant)[5]:

- Boeing B777. Exemption Number 5436, April 1, 1992: Exemption from 14 CFR §25.562 (b) (2) floor warpage for flight deck seats requirement.

- Embraer EMB-145. Certification basis includes Amendment 25-64.

- Fairchild/Dornier 328. Certification basis includes Amendment 25-64.

Based on the above, approximately 5,200 airplanes currently in-service could be affected by some or all of the options enumerated above. This represents approximately 680,000 airplane seats.[6]

2. Seat Distribution Projection

The future distribution of airplane seats depends on several assumptions: 1) the rate at which seats are replaced, 2) the composition of replacement seats, 3) the rate at which older aircraft are retired, 4) the rate at which new airplanes are delivered, and 5) the types of airplanes delivered

i. Seat Replacement Rate

According to comments to Notice 88-8, air carriers "replace seats at intervals ranging from 10 to 21 years, with an average replacement interval of 14 years or more." Commenters estimated that "50 percent of…passenger seats (are) between 13 and 17 years of age."[7] Based on this information, commenters predicted "that only 40 percent of passenger seats in service in 1998 would have been replaced or newly installed since 1989," in the absence of the final rule. By comparison, the FAA estimated in its regulatory evaluation of the Notice that air carriers replace seats, on average, every 7 years.[8]

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5 The DeHavilland DHC-8 Series 200 was certificated as a derivative of the Series 100 aircraft. The applicable basis of certification is the same as the Series 100, but the manufacturer elected to demonstrate compliance with FAR Part 25, up to Amendment 25-66, less exceptions for: 1) FAR 25.365(e), Amendment 25-54; 2) FAR 25.561, Amendment 25-64; 3) FAR 25.562, Amendment 25-64; FAR 25.783, Amendment 25-54; 4) FAR 25.785, Amendment 25-64; FAR 25.904, Amendment 25-62; FAR 25.1091, Amendment 25-57.

6 By way of comparison, a recent regulatory evaluation estimated that by 1998 approximately 5,665 transport category airplanes carrying 698,593 passenger seats would be operating under 14 CFR part 121. Muckle, Archie, *Regulatory Evaluation, Final Regulatory Flexibility Determination and Analysis, Trade Impact Assessment, and Unfunded Mandates Act Determination: Retrofit of Improved Seats in Air Carrier Transport Category Airplanes*, FAA, Office of Aviation Policy and Plans, Operations Regulatory Analysis Branch, April 1998, p 0.

7 *Ibid.*, p 4.

8 *Ibid.*, p 4.

This analysis postulates that seat lives are uniformly distributed with a mean life of 14 years and maximum and minimum lives of 18 and 10 years, respectively. This slightly differs from previous analyses which assumed that all seats of a given vintage are replaced at exactly 14 years (see Figure II.1). The assumption of uniform seat replacement applies both to seats in newly manufactured airplanes and replacement seats (and explains the oscillating pattern of seat replacements over time).[9]

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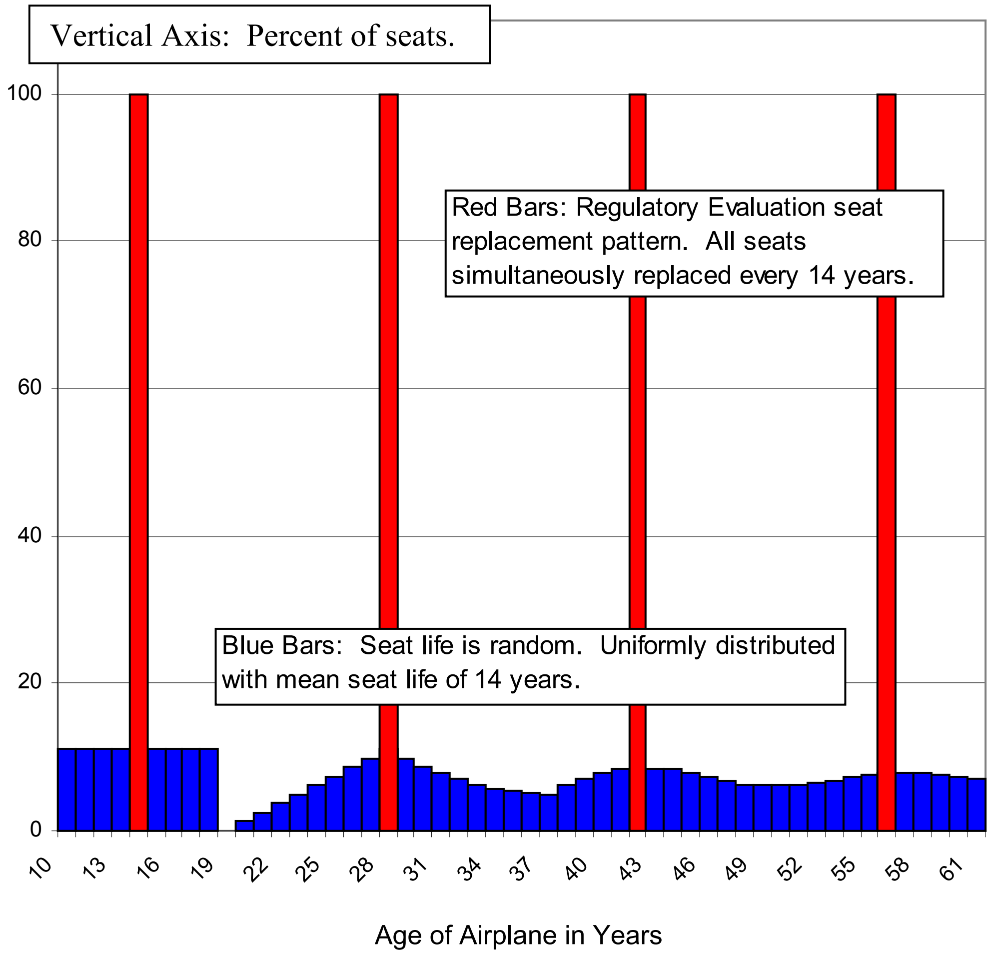
[9] Seat manufacturers report that seats are typically replaced by ship set.

Figure II.1: Comparison of Seat Replacement Assumptions
Hypothetical fleet of airplanes (built in the same year) carrying 10,000 seats.



ii. Composition of Replacement Seats

According to the Draft regulatory evaluation:

> "Although some 16g seat designs may have been produced as early as 1986, the FAA assumes that widespread production and installation of these seats did not occur until the latter part of 1987…This analysis assumes, therefore, that all seats installed from 1992 through 1998 are partial 16g, and costs associated with those seats are not attributed to the final rule. The incremental costs of purchasing and installing 16g seats on airplanes produced after the effective date of the final rule will be assigned in this evaluation as costs of the rule."[10]

While the regulatory evaluation referred to "16g compatible seats," it did not take into consideration possible differences in incremental benefits (or costs) when full TSO-C127a seats are compared with "16g compatible" and "non-16g compatible" seats. Rather, benefits (and costs) were estimated by comparing 16g seats to non-16g seats. This analysis explicitly estimates the relative benefits and costs associated with full 16g seats, partial 16g seats, and 9g seats.

iii. Airplane Service Life

Following the regulatory evaluation, airplanes are assumed to have a service life of 42 years.

iv. Fleet Growth

For the period 2000-2020, annual growth in the number of part 121 passenger seats is estimated by extrapolating the 1998 seat count as follows:

- For 1999-2010, annual growth in the part 121 airplane fleet is estimated using the FAA forecast.[11]

- The forecasted part 121 aircraft count is then multiplied by the forecasted average number of passenger seats per aircraft (again from the FAA forecast) yielding an estimate in the growth rate in the number of passenger seats under part 121.[12]

- The 1998 passenger seat count (obtained from the NASDAC data) is extrapolated forward using the projected seat count for 1999-2010.

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[10] *Ibid.*, p 25.

[11] Table 17, U.S. Commercial Air Carriers—Jet Aircraft, *FAA Aerospace Forecasts Fiscal Years 1999-2010*, FAA Office of Aviation Policy and Plans, March 1999.

[12] *Ibid.*, Table 7.

- The mean annual growth rate for 1999-2010 is applied to extrapolate the time series generated above to the period 2011-2020.

v. Types of Airplanes/Seats delivered.

According to records from the Seattle, Atlanta, and Fort Worth Aircraft Certification Offices (ACO), approximately 53% of current seat certification programs are full 16g, approximately 45% are partial 16g, and approximately 2% are 9g.[13] This finding is at variance with TCDS information, and indicates that some operators are complying with 14 CFR 25.562 even though they are not required to do so.[14] To account for this voluntary industry action, this analysis assumes that the distribution of airplane seats delivered in the future corresponds to 53% full 16g/45% partial 16g/2% 9g.[15]

There are several points to consider:

- This assumption is inconsistent with the 1998 Regulatory Evaluation. In that analysis, benefits for the period 1999-2018 were measured against the performance of 9G seats. In other words, it was assumed that no 16g or partial 16g seats would be installed after 1998 in the absence of a FAA requirement.

- This assumption does not explicitly account for the introduction of new type certificates.

Figure II.2 and Table II.2 show the distribution of airplanes/seat types over time under the assumptions of this section.

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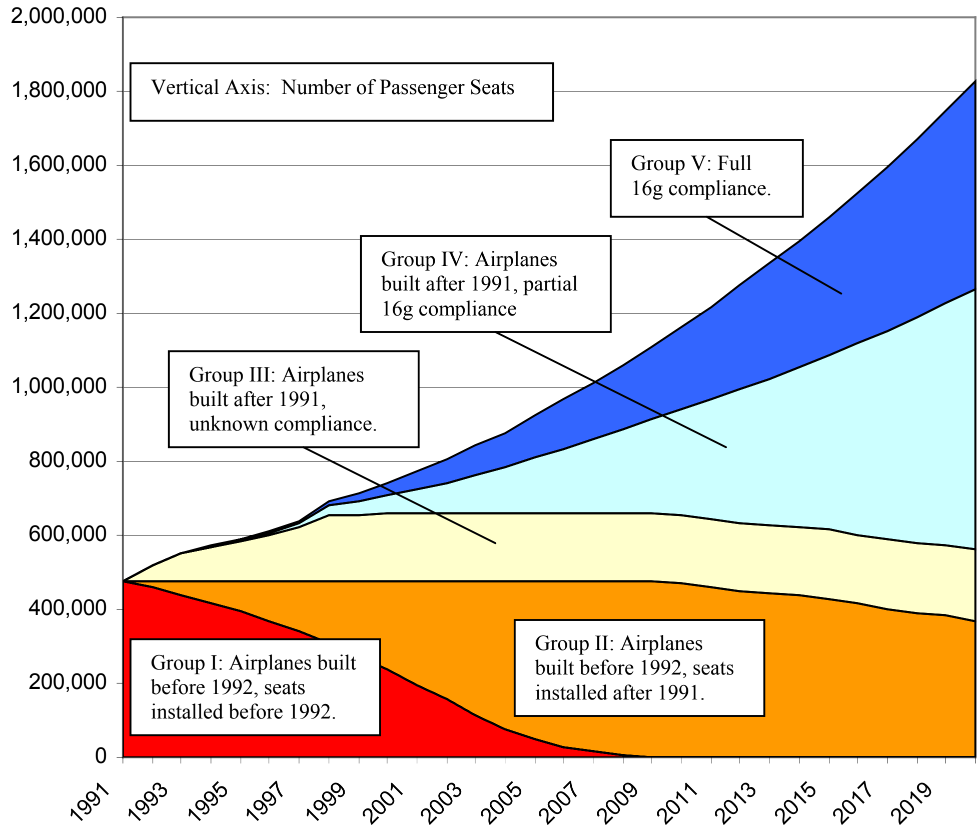
[13] This is an average figure for the three ACO's for the period 1997-1999.

[14] For example, one ACO respondent reported that: "…we can safely say that most (99%?) of [seat certifications] are for 121 operators, and fully .562 compliant (i.e. if HIC testing was not done, a 50" pitch, or head travel data, was imposed for installation.)" Another respondent wrote: "All authorizations were for TSO-C127/127a (some were eventually installed on A/C for which full compliance wasn't necessary and HIC testing was not performed. However, full compliance to the TSO was met by showing no contact at a specified seat pitch)."

[15] This assumption differs from the 1998 Regulatory Evaluation which implicitly ascribed all future 16g seat installation to the proposed rulemaking. Some observers (within APO and AIR) have questioned whether current industry behavior—which may be affected by the *threat* of a rulemaking—can be extrapolated into the future if the threat of rulemaking is withdrawn.

Figure II.2: Baseline Seat Projections
Distribution of Airplanes/Seat Types Over Time, 1991-2020



Assumptions:

1. Airplanes retired after 42 years of service.
2. Seat replacement uniformly distributed with mean seat life of 14 years.
3. Fleet/seat growth based on *FAA Aerospace Forecast*.
4. Proportion of future full 16g/partial 16g seats constant.

Table II.2: Baseline Seat Distribution Forecast by Seat Type
(U.S. 14 CFR part 121 passenger seats only)

	Group I	Group II	Group III	Group IV	Group V
1999	272,720	205,271	178,598	36,534	22,960
2000	235,773	242,218	178,852	50,512	34,143
2001	194,919	283,072	179,154	67,114	47,424
2002	154,523	323,304	179,483	85,209	61,900
2003	115,007	362,820	179,857	105,771	78,349
2004	77,682	400,025	180,218	125,642	94,246
2005	46,440	431,215	180,680	151,045	114,569
2006	26,910	450,745	181,091	173,633	132,639
2007	13,760	463,791	181,556	199,219	153,108
2008	4,650	472,531	182,039	225,754	174,336
2009	0	476,011	182,555	254,147	197,050
2010	0	469,770	183,160	287,429	223,676
2011	0	459,375	183,801	322,679	251,876
2012	0	448,921	184,467	359,324	281,192
2013	0	442,791	185,116	395,016	309,746
2014	0	437,926	185,779	431,504	338,936
2015	0	427,412	186,528	472,658	371,859
2016	0	414,061	187,334	517,004	407,336
2017	0	399,673	188,182	563,627	444,635
2018	0	388,254	189,032	610,404	482,056
2019	0	381,358	189,871	656,560	518,981
2020	0	368,871	190,802	707,746	559,930

Figure II.2 and Table II.2 break down the future distribution of seat types into five groups:

- Group I: Airplanes manufactured before 1992 having seats installed before 1992. While 16g seats were being installed before this date, the majority of these seats are 9g.

- Group II: Airplanes manufactured before 1992 having replacement seats installed after 1991. Some (unknown) proportion of seats in this group may have partial 16g performance although no airplane model in this group is 16g certificated. Note that the sum of Group I and Group II declines over time as these airplanes/seats are retired from passenger service.

- Group III: Airplanes manufactured after 1991. Some (unknown) proportion of seats in this group may have partial 16g performance.

- Group IV: Airplanes manufactured after 1992 and compliant with some parts of 14 CFR §25.562 (certificated partial 16g capability).

- Group V: Airplanes manufactured after 1992 and fully compliant with 14 CFR §25.562 (e.g. certification basis includes Amendment 25-64, or full 16g testing was performed voluntarily).

Two critical questions are: 1) What is the performance of Group II/III seat installations relative to full 16g and partial 16g installations? 2) How will the composition of Group II/III installations change over time? Will operators continue to upgrade these seats in the absence of rulemaking?

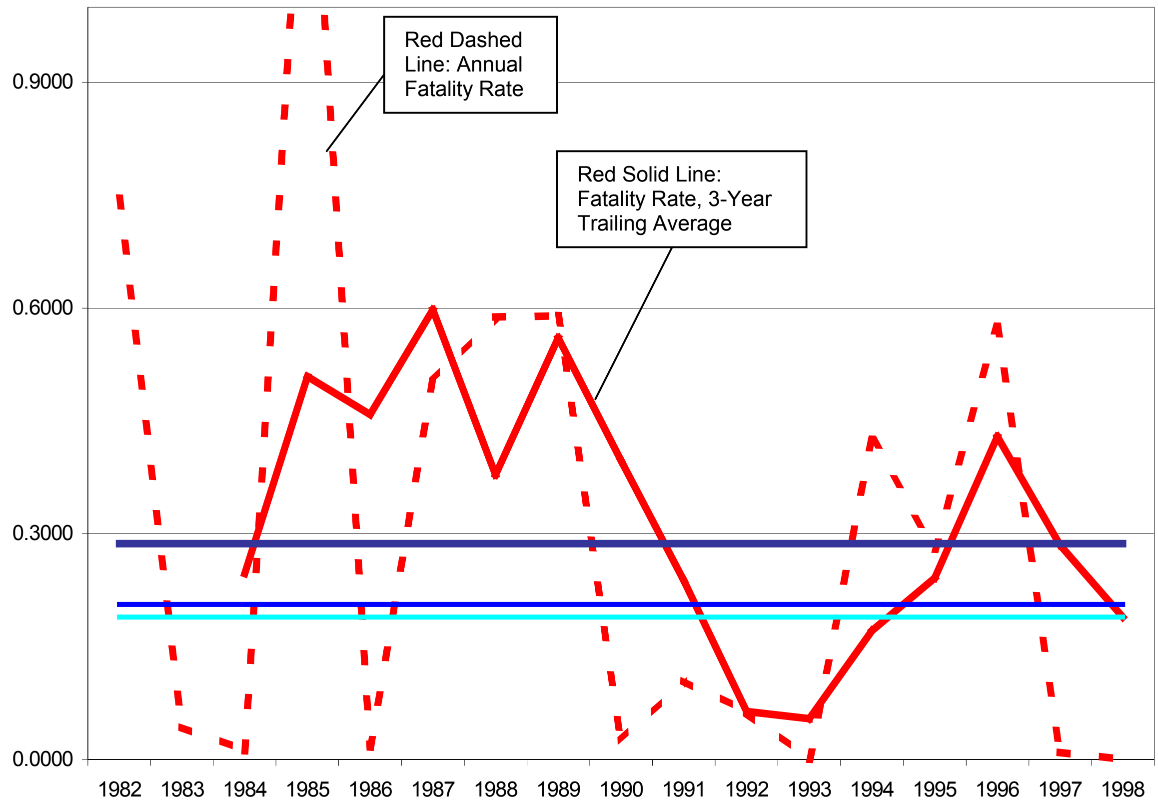
C. Projected Casualty Rates

Projected (2000-2020) fatality and serious injury rates are equal to the fatality and injury rates for U.S. 14 CFR part 121 (scheduled and nonscheduled) operations for the period 1984-1998 (the time period used in the Cherry study—see below). Casualty and activity data are summarized in Table II.3. Alternative casualty rate assumptions are illustrated in Figure II.3.

Table II.3: NTSB U.S. 14 CFR part 121 Accident and Activity Data, 1982-1998
(Source: NTSB website, January 2000.)

Year	Accidents		Fatalities		Injuries			
	All	**Fatal**	**Total**	**Aboard**	**Serious**	**Flight Hours**	**Departures**	**Enplane (mil)**
1982	18	5	235	223	17	7,040,325	5,351,133	299.0
1983	23	4	15	14	8	7,298,799	5,444,374	325.0
1984	16	1	4	4	6	8,165,124	5,898,852	352.0
1985	21	7	526	525	20	8,709,894	6,306,759	390.0
1986	24	3	8	7	23	9,976,104	7,202,027	427.0
1987	34	5	232	230	39	10,645,192	7,601,373	458.0
1988	30	3	285	274	44	11,140,548	7,716,061	466.0
1989	28	11	278	276	55	11,274,543	7,645,494	468.0
1990	24	6	39	12	23	12,150,116	8,092,306	483.0
1991	26	4	62	49	19	11,780,610	7,814,875	468.0
1992	18	4	33	31	14	12,359,715	7,880,707	494.0
1993	23	1	1	0	7	12,706,206	8,073,173	515.6
1994	23	4	239	237	16	13,124,315	8,238,306	557.6
1995	36	3	168	162	15	13,505,257	8,457,465	579.7
1996	38	5	380	350	19	13,746,112	8,228,810	608.1
1997	49	4	8	6	19	15,829,408	10,300,040	630.6
1998	48	1	1	0	10	16,508,000	10,318,000	643.3
1984-98	**438**	**62**	**2,264**	**2,163**	**329**	**181,621,144**	**119,774,248**	**7,540.9**
1989-98	**313**	**43**	**1,209**	**1,123**	**197**	**132,984,282**	**85,049,176**	**5,447.9**
1996-98	**135**	**10**	**389**	**356**	**48**	**46,083,520**	**28,846,850**	**1,882.0**

Figure II.3: U.S. Fatality Rates, 14 CFR Part 121
Scheduled and Non-Scheduled, 1982-1998 (Source: NTSB)
(Fatalities per million enplanements)



Notes: 1) Dark blue line. Mean fatality rate for the period 1984-1998 (the study period of the Cherry Benefits Analysis): 0.2868 per million enplanements.

2) Blue line. Mean fatality rate for the period 1989-1998. 0.2061 per million enplanements.

3) Light blue line. Mean fatality rate for the three year period 1996-1998: 0.1892 per million enplanements.

D. Risk Reduction Estimates and Relative Performance by Seat Type

Estimates of the safety benefits of 16g seats are based on a study of 25 impact-related accidents involving airplanes operating under 14 CFR part 121 (or equivalent) during the period 1984-1998 undertaken by R.G.W. Cherry and Associates (*Cherry Benefits Analysis*).[16] The analytical approach is illustrated in Figure 4. Each accident in the *Cherry Benefits Analysis* is divided into "scenarios"—volumes of an aircraft in which occupants are subjected to similar risks.[17] In the example, there are 100 occupants in the scenario, of which: 45 are uninjured survivors, 25 suffer serious injuries either from impact, fire or both, and 30 are killed either from impact, fire or both.

Based on engineering assessments of the possible effects of full 16g seats, Monte Carlo simulations were used to assess a high, median and low value for the total achievable (net) reduction in fatalities and serious injuries for each accident/scenario. Risk reduction benefits for the U.S. part 121 fleet, then, were estimated in three ways:

First, Cherry estimated the number of averted U.S. casualties by assuming that the ratio of U.S./World casualties averted is proportional to the ratio of U.S./World accidents (see Table II.4).[18] Second, they estimated the number of U.S. casualties averted strictly based on the part 121 accidents studied (Table II.5). Third, they extrapolated the U.S. specific data, to U.S. part 121 ground-impact accidents that were not studied.[19]

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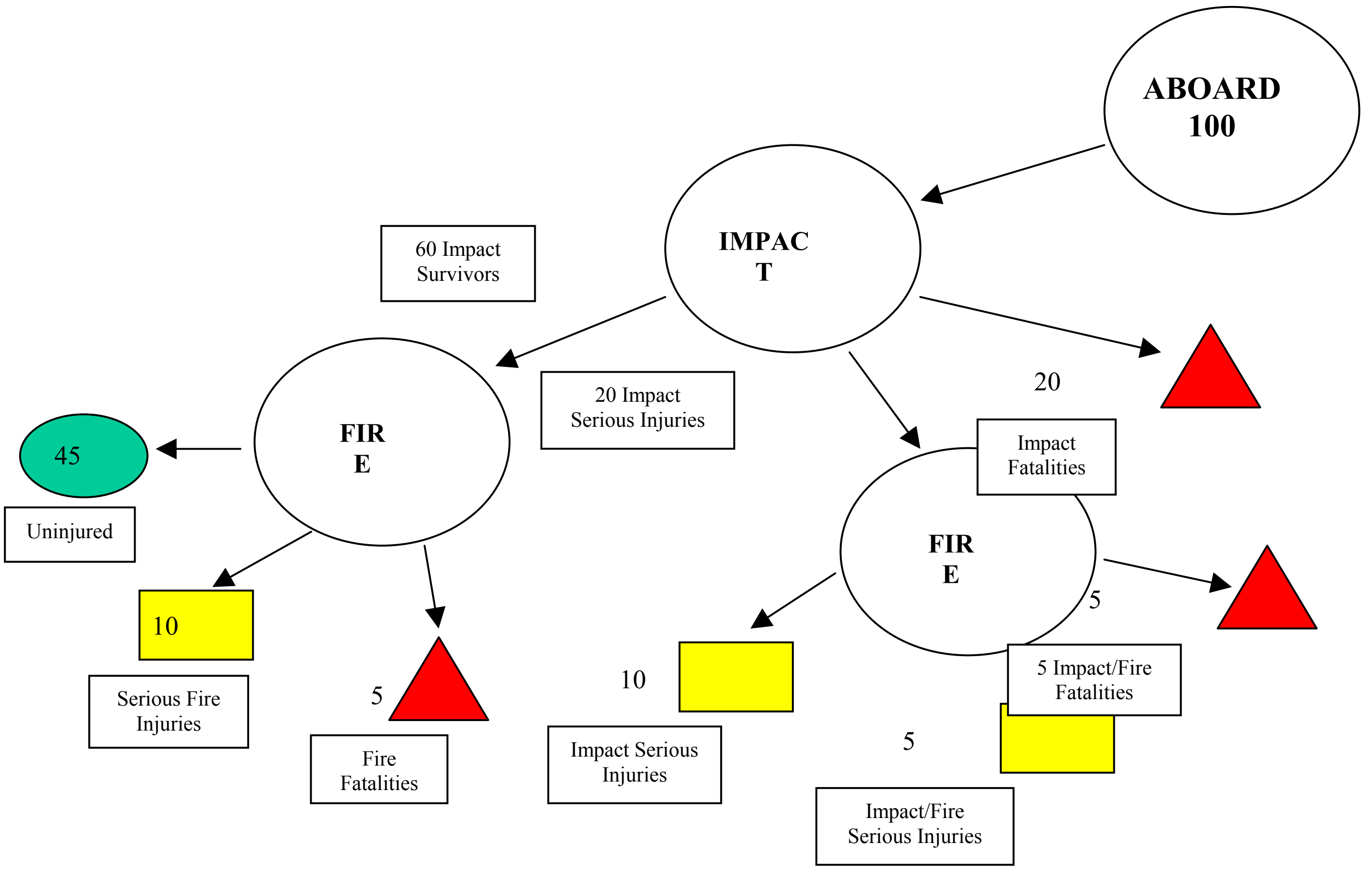
[16] R.G.W. Cherry & Associates Limited, *A Benefit Analysis for Aircraft 16G Dynamic Seats*, Issues 1 and 2, 1999.

[17] *Ibid.*, p 11.

[18] In this case, "World" accidents refer to events involving non-U.S. carriers that are operated under regulatory requirements similar to part 121 (in the estimation of Cherry). The accident proportion is calculated using a set of ground-impact accidents selected for study by Cherry. In fact, the ratio of U.S./World casualties is less that the ratio of U.S./World accidents. I.e., there are fewer preventable casualties, at least in the accident set studied, involving U.S. carriers versus world carriers as a whole.

[19] Cherry's methodology begs the question: "Is there a statistical difference between the characteristics of 'World' ground-impact accidents versus the 'U.S. part 121 only' subset?" The AIR/ASY team conducted two statistical tests that compared the "World" and "U.S." samples: 1) a standard parametric test (assuming two independent random samples from two normal populations with common, but unknown, variances), and 2) a non-parametric test (Wilcoxon Rank-Sum). In the two-tailed test of "World" and "U.S." mean fatalities and injuries, the critical region $|t| \geq t_{0.025,23} = 2.069$. The computed values of t were –0.155 and 2.034 for fatalities and injuries, respectively. For the Wilcoxon Rank-Sum test, z = 0.435 and 1.904 for fatalities and injuries, respectively. So one cannot reject the hypothesis that the samples are drawn from the same "risk" population (at the 5% level).

Figure II.4: Cherry Methodology For Estimating 16g Benefits



For each method ("World," "U.S.," and "Adjusted U.S."), Cherry showed low, median, and high casualty estimates (based on Monte Carlo simulations of 16g seat performance). The following tables summarize the Cherry results. (For comparison, 1998 Regulatory Evaluation estimates of the number of fatalities and injuries averted are shown in Table II.7. These estimates were derived from an analysis of accidents during the period 1970 to 1983, and were adjusted to reflect the decreasing accident rate.)[20]

Table II.4: Part 121 Estimates of Casualties Averted
Extrapolated From World Data, 1984-1998

	Low	Median	High
Fatalities	33	51	68
Serious Injuries	28	54	79

Table II.5: Part 121 Estimates of Casualties Averted
Based on the Part 121 Accidents Studied, 1984-1998

	Low	Median	High
Fatalities	8	16	27
Serious Injuries	-1	12	22

Table II.6: Part 121 Estimates of Casualties Averted Adjusted to Include
Ground-Impact Accidents Not Studied, 1984-1998

	Low	Median	High
Fatalities	12	23	40
Serious Injuries	-1	18	32

Table II.7: Estimated Number of Casualties Prevented, 1970-1983 (Adjusted)
(1998 Regulatory Evaluation)

	Low	Median	High
Fatalities	45	na	88
Serious Injuries	48	na	52

[20] "While the historical estimate is a useful baseline for determining the rate of fatalities and serious injuries caused by seat performance, it must be adjusted to take into consideration that the average number of accidents occurring annually (from all causes) has declined over time. For the period of the report [FAA Technical Report, *Transport Controlled Impact Demonstration Seat Experiments and Cost Benefit Study*, DOT/FAA/CT-85/36, October 1986]—1970 through 1983—there were an average of 29 accidents annually (for all part 121 scheduled operations). In the subsequent period—1984 through 1996—there were 23.5 accidents per year, an 18 percent decrease…Accordingly, the FAA has adjusted the historical estimates of fatalities and injuries due to seat failure down by 18 percent…" Muckle, Archie, *Regulatory Evaluation..*, *op. cit.*, p 38.

Benefits, then, are estimated using two assumptions: 1) The reduction in fatalities and serious injuries is based on the World accident data from Table II.4. 2) The high end of the benefits range is assumed. The rationale for assumption 1 is that, while the accident *rates* between world and U.S. commercial operators may be different, there is less compelling evidence that the accident *characteristics* are different (see footnote 19).[21]

The rationale for assumption 2 is that the low end of the benefits range inappropriately adjusts for "better-than 9g" seats. As noted earlier, the Cherry study includes accidents from the period 1984 to 1998. But Cherry does not differentiate the relative benefits of 9g versus partial 16g, 9g versus full 16g, or partial 16g versus full 16g—all benefits are represented as approximations of the benefits of full 16g seats relative to 9g seats. In fact, seats installed after 1992 probably perform much better than 9g seats. Therefore, it is possible that benefits are undercounted for some accidents.

For example, suppose that in a given accident/scenario no seats/tracks were observed to fail. This could be taken as evidence that there were no incremental benefits available to 16g seats. On the other hand, the performance of the seats could be attributable to the fact that they were already partial 16g. Because many seats have partial 16g performance without corresponding certification, it is possible that low benefit estimates could reflect the superior performance of existing seats.

Table II.3 shows that, during the period 1984-1998, part 121 carriers accumulated approximately 7.541 billion enplanements. Table II.8 shows the estimated reduction in fatalities and injuries per billion enplanements using the Cherry worldwide accident analysis from Table II.4 (for comparison, the 1998 Regulatory Evaluation estimated reduction in the rate of casualties is shown in Table II.9).

Table II.8: Part 121 Estimated Reduction in the Casualty Rate
Extrapolated From World Data, 1984-1998 (Per Billion Enplanements)

	Low	Median	High
Fatalities	4.3761	6.7631	9.0175
Serious Injuries	3.7131	7.1609	10.4762

21 Benefits depend on: 1) accident/casualty rates, and 2) the degree to which 16g seats would reduce casualties in a typical or average accident. It is important to emphasize that the benefits of this study are based on the U.S. part 121 accident rate. The degree to which 16g seats reduce risks is based on an analysis of world accidents. The rationale for this is that a typical U.S. accident is not significantly different from a typical non-U.S. accident in terms of accident outcomes.

Table II.9: Estimated Number of Casualties Prevented Per Billion Enplanements
(1998 Regulatory Evaluation)

	Low	Median	High
Fatalities	13.28	na	25.97
Serious Injuries	14.16	na	15.34

This analysis expresses the reduction in risk as a proportion of the fatality rate. For example, according to NTSB records (Table II.3) there were approximately 2,163 fatalities and 329 serious injuries during the period 1984-1998. Therefore, based on the World accident data analysis (Table II.4), 16g seats could have reduced fatalities and serious injuries during that period by up to 3.14% and 24.01%, respectively ("high" estimate).

Table II.10: Estimated Reduction in Casualties as a Percent of
Total U.S. Casualties (Based on Cherry World Data)

	Low	Median	High
Fatalities	1.526%	2.358%	3.144%
Serious Injuries	8.511%	16.413%	24.012%

E. Adjustment Factors For Different Vintages of Seats

The *Cherry Benefits Analysis* gives an estimate of the benefits available to full 16g seats. The comparison of options, however, also requires estimates of the relative performance of 9g and partial 16g seats. Therefore, engineering judgement was used to estimate the relative performance of various classes of airplanes/seats.

Table II.11: Benefit Factors by Airplane/Seat Group

Group I Airplanes built before 1992: 9g Seats	**Group II** Airplanes built before 1992: Unknown % partial 16g	**Group III** Airplanes built after 1991: Unknown % partial 16g	**Group IV** Airplanes certificated compliant with parts of 25.562	**Group V** Full 16g airplanes.
0.0	0.1	0.2	0.5	1.0

Group V (full 16g certificated airplanes/seats) are assumed to have a benefit factor of 1.0—that is, the full risk reduction estimates (relative to 9g seats) shown in Table II.10 are assumed to apply. Group IV~~I~~ (certificated partial 16g airplanes/seats) are assumed to a benefit factor of 0.5—that is, certificated partial 16g installations are assumed to have 50% of the casualty-averting benefits of full 16g seats. This rating follows since a large fraction of the benefits of

16g seats are ascribed to the occupant injury criteria. Group I seats (mostly 9g) are assumed to have a factor of 0.0. Risk reduction factors by Group are shown in Table II.11.

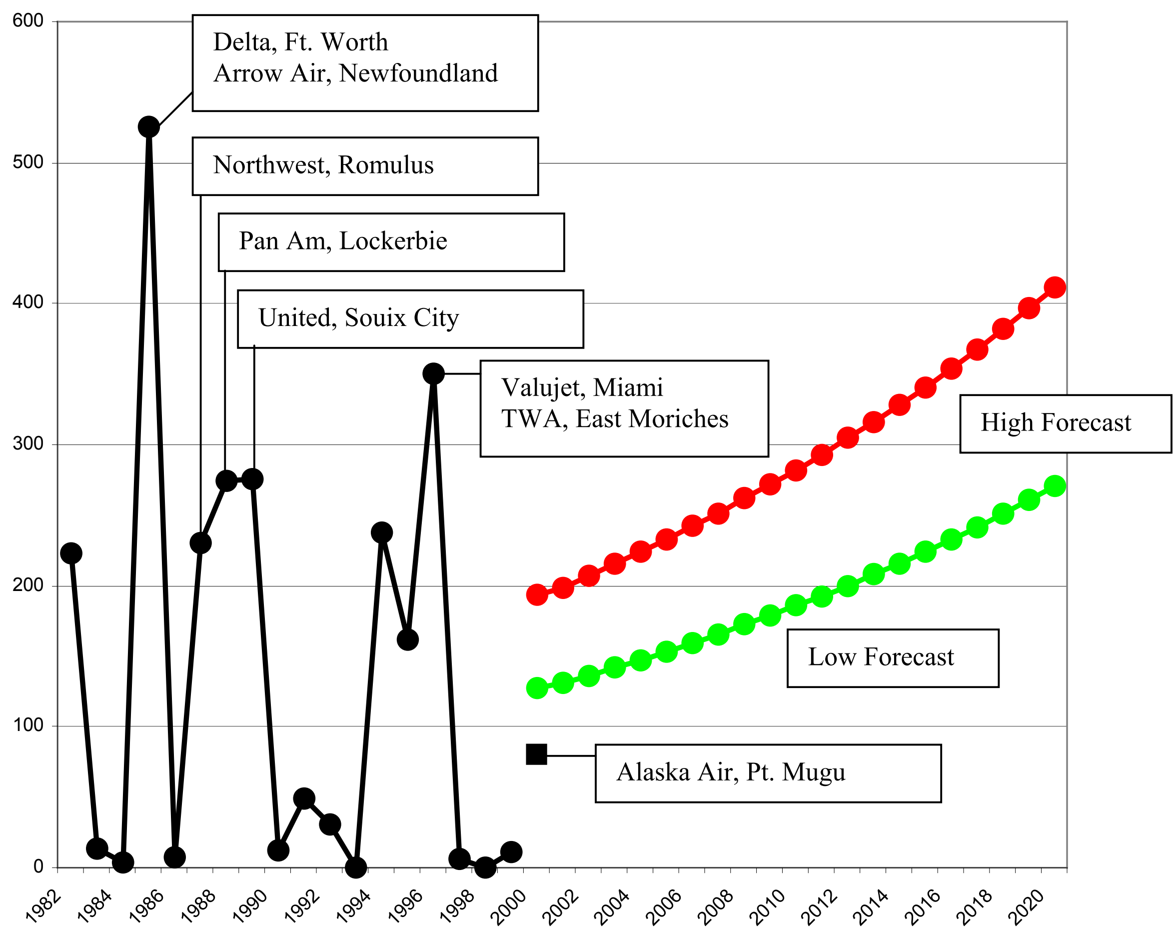
Group II/III seats are assumed to have relatively low performance (10% and 20%, respectively). In addition to the factors cited above, this rating reflects: 1) uncertainty regarding the performance of these seats due to the absence of test data, and 2) uncertainty regarding the future installation of seats given the absence of rulemaking and changing economic conditions.

F. Forecast of Baseline Fatalities and Injuries

As noted above, baseline forecasts of fatalities and injuries are constructed for each of the five aircraft/seat/installation groups. Benefits, then, are estimated by projecting how each option affects the baseline seat distribution.

Figure II.5 compares historical 14 CFR part 121 fatalities with projected fatalities. The figure graphically illustrates the familiar result that, if the fatality rate is constant, fatalities will increase as operations/enplanements increase.

Figure II.5: Historical and Projected Fatalities, 1982-2020
(Preliminary 1999: 11 total fatalities, NTSB website, March 2000)



Notes: 1) Black Line. Actual fatalities (total onboard) for U.S. 14 CFR part 121 operators (scheduled and nonscheduled), 1982-1999. Source: NTSB.

2) Black Square. Alaska Air accident.

3) Red Line. Forecasted onboard fatalities for 2000-2020 assuming a future passenger fatality rate of 0..2868 per million enplanements (the mean U.S. 14 CFR part 121 fatality rate for the period 1984-1998—the study period of the *Cherry Benefits Analysis*). Future enplanements taken from the FAA Aerospace Forecast, 1999-2010.

4) Green Line. Forecasted onboard fatalities for 2000-2020 assuming a future passenger fatality rate of 0.1892 per million enplanements (the mean U.S. 14 CFR part 121 fatality rate for the three-year period ending in 1998).

III. Cost Methodology and Baseline Cost Estimates

A. Summary of Costs

The sources of costs are summarized in Table III.1, which compares the five options considered in this study with the results of the 1998 draft regulatory analysis. The 1998 analysis considered a proposal which would have required full 16g compliance for newly manufactured airplanes and full 16g retrofit for in-service airplanes (see also Table ES-1). As noted above, the regulatory evaluation identified seat weight, seat replacement, and seat certification as the largest sources of incremental costs.

Table III.1: Sources of Costs By Option

	Passenger Seats					Cabin Attendant Seats			
	Cert.	Seat Install & A/C Mod	Seat Cost/ Early Repl.	Down-Time	Wt.	Cert.	Seat Install & A/C Mod.	Early Repl.	Wt
Rev. Eval.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Option 1									
Option 2	✓					✓			✓
Option 3	✓	✓	✓			✓	✓	✓	✓
Option 4	✓					✓	✓	✓	✓
Option 5	✓					✓	✓	✓	✓

New information provided by seat manufacturers indicates that, at least with respect to passenger seats, incremental weight and cost effects are negligible. In fact, modern 16g seats are in some cases lighter than older 14g seats. In addition, the options considered in this analysis emphasize "discretionary replacement;" that is, requiring compliance for in-service aircraft only when operators choose to replace seats (rather than stipulating a mandatory retrofit period).

The following discussion outlines the process used to determine baseline passenger and flight attendant seat costs.

B. Passenger Seats

1. Passenger Seat Certification Costs

The process used to estimate certification costs is outlined below:

- Step1: Estimate the number current certification programs.
- Step 2: Extrapolate the current number of certification programs into the future.
- Step 3: Determine the current distribution of seat certification programs (9g, partial 16g, full 16g).
- Step 4: Determine the average cost of a certification program.
- Step 5: Determine the stream of future certification program costs based under the baseline assumption.
- Step 6: Determine the stream of future certification program costs under each alternative option and compare to the baseline to calculated incremental certification costs.

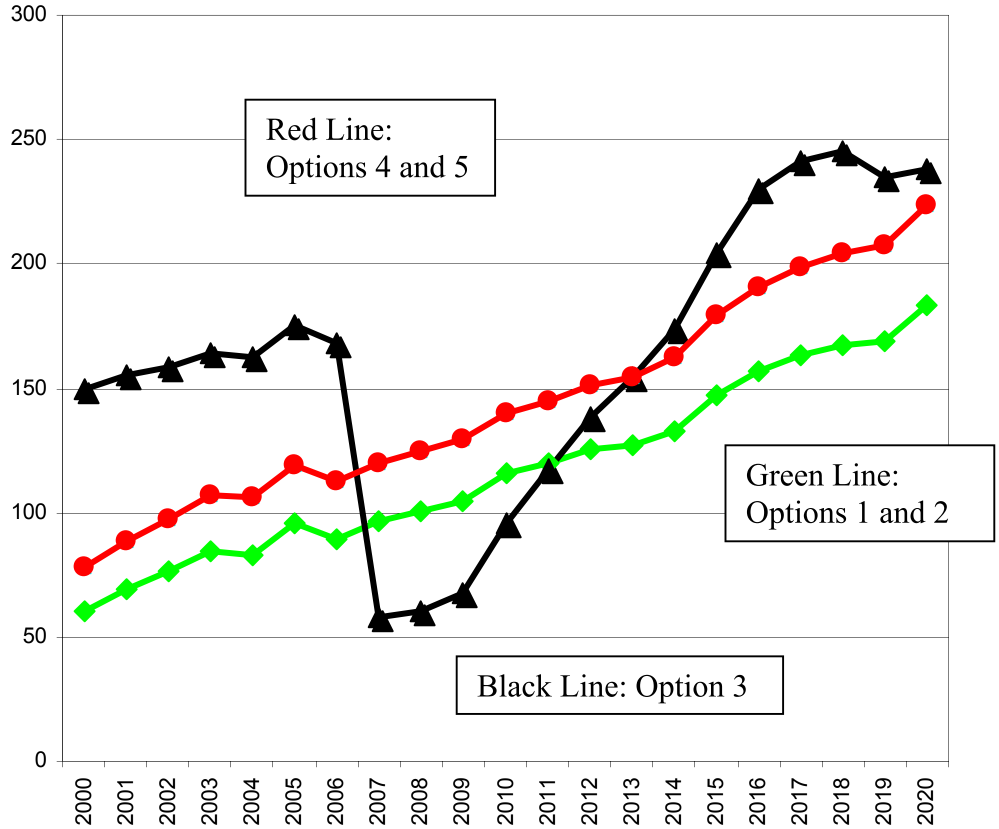
Step 1: Estimate number and distribution of current certification programs. Information on the number and distribution of current seat certification programs was obtained from the Seattle, Atlanta, and Fort Worth Aircraft Certification Offices (ACO). This information is summarized in Table III.2.

Table III.2: Number and Distribution of Seat Certification Programs, 1997-1999

	1997	1998	1999
Programs	74	128	158
Distribution			
Full 16g	0.595	0.695	0.373
Partial 16g	0.392	0.297	0.601
C39b	0.014	0.008	0.025

Step 2: Extrapolate the current number of certification programs into the future. The current number of certification programs was extrapolated forwarded using the rate of growth in the number of seat replacements and installations. That is, the number of seat certification programs in the future is assumed to be a constant fraction of the number of seats installed/replaced. Figure III.1 shows the number of passenger and flight attendant seat certifications predicted for this analysis.

Figure III.1: Predicted Number of Seat Certifications (Domestic Only)
Passenger and Flight Attendant Seat Certifications



Notes: 1) Green Line: The number of passenger and flight attendant certifications (full 16g, partial 16g, and 9g) projected under the baseline and Option 2 (full 16g seats for newly manufactured airplanes only).

2) Red Line: The number of passenger and flight attendant certifications projected under Options 4 and 5 (discretionary replacement of passenger seats, flight attendant seats must be replaced when passenger seats are replaced).

3) Black line: The number of seat certifications projected under Option 3 (full 16g seats for newly manufactured airplanes, mandatory retrofit for in-service airplanes by 2007.

Example: An average of 120 new aircraft passenger seat certification programs were processed annually between 1997-1999 according to FAA ACO information. Of this total, approximately 16.5% were for U.S. part 121 air carriers, about 19.7 passenger seat certification programs per year (for new aircraft deliveries).

In 2000, the FAA estimates that approximately 25,415 passenger seats will be installed in newly manufactured aircraft. Therefore, approximately 1,290~~87~~ passenger seats are installed per certification program. Assuming this ratio holds true for replacement seats, the FAA estimates that—in the absence of rulemaking—approximately 48 passenger seat certification programs will be conducted for U.S. part 121 operators in 2000.

If the ratio of installed/replaced seats per certification is approximately constant during the forecast time period, then the (baseline) number of certification programs is:

Table III.3: Baseline Certification Program Forecast, 2000-2020

	Passenger Seats	Cabin Attend. Seats	Total Seats
2000	48	12	60
2001	55	14	69
2002	61	16	76
2003	66	18	84
2004	66	17	83
2005	74	22	96
2006	70	19	89
2007	74	22	96
2008	78	23	100
2009	80	24	105
2010	87	29	116
2011	90	30	120
2012	94	31	125
2013	96	31	127
2014	101	31	132
2015	112	35	147
2016	119	38	157
2017	124	40	164
2018	127	40	167
2019	129	40	169
2020	139	44	183

Step 3: Determine the current distribution of seat certification programs. The current distribution of seat certification programs was estimated directly from the ACO data for the period 1997-1999 (see Table III.2). The data show that approximately 44% of current programs are full 16g, 55% of current programs are partial 16g, and 1% of programs are 9g.[22]

[22] Note that this is at variance with estimates provided by industry which show a much lower percentage of full 16g programs. According to two of the ACO's "…most (99%) of the current certification programs are for 121

Step 4: Determine the average cost of each type of certification program. The estimated average costs of full 16g, partial 16g, and 9g certification programs are, respectively: $300,000; $150,000; and $40,000.

9g Certification: According to data supplied by industry, the cost of a 9g certification can range from a low of $2,000 (in the case of a follow-on program which does not require additional static testing) to $15,000 (in the case of a new certification for an economy class seat) to over $100,000 for a premium class seat. The estimated $40,000 cost reflects the costs of 5 static tests, 5 test articles, labor, documentation/data, and certification fees and is based on industry estimates of (weighted) average certification costs.

Partial 16g Certification. The estimated $150,000 average cost reflects 5-7 tests (without HIC), test article costs, labor, documentation/data, and certification fees.

Full 16g Certification. Full 16g certification cost estimates supplied by industry ranged from $30,000 (where no additional testing is required and full similarity justification is possible) to over $800,000 for a premium class seat. The $300,000 estimate represents an industry average program cost that includes 12-15 tests for full certification (including HIC), test articles, labor, documentation/data, and certification fees.

Step 5: Determine baseline certification costs. Baseline certification costs are determined by multiplying the number of certification programs (by type) by its associated average (per certification program) cost. The calculations are shown in Table III.4:

2. Passenger Seat Replacement Costs

Incremental seat replacement costs (including installation labor and seat procurement costs) are estimated by comparing the baseline stream of seat expenditures (assuming all baseline seat installations are discretionary[23]) with the stream of seat expenditures under each alternative option. As a result, incremental seat replacement costs in this analysis only occur when a non-discretionary retrofit program is imposed on the industry (in other words, incremental replacements costs are only associated with Option 3).

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operators and fully .562 compliant…i.e. if HIC testing was not done, a 50" pitch, or head travel data, was imposed for installation." *This was true even if full 16g was not required for certification*.

[23] As noted elsewhere, this assumption is important. Some observers contend that the current pattern of seat replacements is not discretionary, but, rather, reflects the anticipation by industry that 16g requirements will be imposed in the near future. This analysis makes the assumption that the observed current pattern of replacements will hold true in the future in the absence of regulation.

Table III.4: Forecasted Baseline Certification Cost Stream
(Undiscounted millions of dollars)

	Seats in New Airplane				Replacement Seats			
	Total	**9g**	**16g Partial**	**16g Full**	**Total**	**9g**	**16g Partial**	**16g Full**
2,000	$4.23	$0.08	$1.18	$2.96	$1.15	$1.15	$0.00	$0.00
2,001	$5.02	$0.09	$1.41	$3.52	$1.27	$1.27	$0.00	$0.00
2,002	$5.47	$0.10	$1.53	$3.83	$1.41	$1.41	$0.00	$0.00
2,003	$6.22	$0.12	$1.74	$4.36	$1.50	$1.50	$0.00	$0.00
2,004	$6.01	$0.11	$1.68	$4.21	$1.52	$1.52	$0.00	$0.00
2,005	$7.68	$0.14	$2.15	$5.38	$1.52	$1.52	$0.00	$0.00
2,006	$6.83	$0.13	$1.91	$4.79	$1.52	$1.52	$0.00	$0.00
2,007	$7.74	$0.14	$2.17	$5.42	$1.53	$1.53	$0.00	$0.00
2,008	$8.02	$0.15	$2.25	$5.62	$1.60	$1.60	$0.00	$0.00
2,009	$8.58	$0.16	$2.41	$6.02	$1.97	$1.53	$0.12	$0.31
2,010	$10.06	$0.19	$2.82	$7.05	$2.34	$1.45	$0.26	$0.64
2,011	$10.66	$0.20	$2.99	$7.47	$2.80	$1.36	$0.41	$1.03
2,012	$11.08	$0.21	$3.11	$7.77	$3.37	$1.33	$0.58	$1.46
2,013	$10.79	$0.20	$3.03	$7.56	$4.08	$1.36	$0.78	$1.94
2,014	$11.03	$0.21	$3.09	$7.73	$4.77	$1.40	$0.96	$2.41
2,015	$12.44	$0.23	$3.49	$8.72	$5.62	$1.41	$1.20	$3.01
2,016	$13.41	$0.25	$3.76	$9.40	$6.35	$1.39	$1.42	$3.54
2,017	$14.09	$0.26	$3.95	$9.88	$7.11	$1.32	$1.66	$4.14
2,018	$14.14	$0.26	$3.96	$9.91	$7.60	$1.36	$1.78	$4.46
2,019	$13.95	$0.26	$3.91	$9.78	$8.16	$1.40	$1.93	$4.83
2,020	$15.47	$0.29	$4.34	$10.85	$8.82	$1.41	$2.12	$5.29

C. Flight Attendant Seats

1. Flight Attendant Seat Certification Costs

The same six step process used to estimate passenger seat certification costs was applied to the estimation of incremental flight attendant seat certification costs: 1) estimate the number of current certification programs, 2) extrapolate the current number of certification programs into the future, 3) determine the current distribution of seat certification programs, 4) determine the average cost of a certification program, 5) determine the stream of future certification program costs under the baseline assumption, 6) determine the stream of future certification program costs under each alternative option and compare the baseline to calculated incremental certification costs.

Current and projected number of certification programs. The current number of flight attendant seat certification programs was estimated from industry sources and extrapolated using the process described above. As before, the ratio of certification programs to seats install/replaced is assumed to be roughly constant during the 2000-2020 forecast period. Following the assumption used in the 1998 regulatory evaluation, flight attendant seats are assumed to equal 2% of passenger seats; that is, one flight attendant seat per 50 passenger seats.

Current and projected distribution of flight attendant seat certification programs. The current distribution of flight attendant seat certification programs was determined from data obtained from industry: 1) full 16g, approximately 33%, 2) partial 16g, approximately 42%, 3) 9g, approximately 25%.[24] Again, in the absence of additional rulemaking, this distribution is assumed to be constant during the forecast period.

[24] Note that the percentage of 9g flight attendant seat certification programs is much higher than the percentage of 9g passenger seat certifications.

Table III.5: Forecasted Baseline Flight Attendant Seat Certification Cost Stream (Undiscounted millions of dollars)

	F/A Seats in New Airplanes				F/A Seats Replacement Seats			
	Total	**9g**	**16g partial**	**16g Full**	**Total**	**9g**	**16g partial**	**16g Full**
2000	$2.83	$0.22	$1.09	$1.52	$0.00	$0.00	$0.00	$0.00
2001	$3.36	$0.26	$1.30	$1.81	$0.00	$0.00	$0.00	$0.00
2002	$3.67	$0.28	$1.41	$1.97	$0.00	$0.00	$0.00	$0.00
2003	$4.16	$0.32	$1.61	$2.24	$0.00	$0.00	$0.00	$0.00
2004	$4.03	$0.31	$1.55	$2.16	$0.00	$0.00	$0.00	$0.00
2005	$5.15	$0.40	$1.98	$2.76	$0.00	$0.00	$0.00	$0.00
2006	$4.58	$0.35	$1.76	$2.46	$0.00	$0.00	$0.00	$0.00
2007	$5.18	$0.40	$2.00	$2.78	$0.00	$0.00	$0.00	$0.00
2008	$5.37	$0.41	$2.07	$2.89	$0.00	$0.00	$0.00	$0.00
2009	$5.75	$0.44	$2.22	$3.09	$0.00	$0.00	$0.00	$0.00
2010	$6.74	$0.52	$2.60	$3.62	$0.00	$0.00	$0.00	$0.00
2011	$7.14	$0.55	$2.75	$3.84	$0.00	$0.00	$0.00	$0.00
2012	$7.42	$0.57	$2.86	$3.99	$0.00	$0.00	$0.00	$0.00
2013	$7.23	$0.56	$2.79	$3.88	$0.00	$0.00	$0.00	$0.00
2014	$7.39	$0.57	$2.85	$3.97	$0.00	$0.00	$0.00	$0.00
2015	$8.34	$0.64	$3.22	$4.48	$0.00	$0.00	$0.00	$0.00
2016	$8.98	$0.69	$3.46	$4.83	$0.00	$0.00	$0.00	$0.00
2017	$9.44	$0.73	$3.64	$5.07	$0.00	$0.00	$0.00	$0.00
2018	$9.47	$0.73	$3.65	$5.09	$0.00	$0.00	$0.00	$0.00
2019	$9.35	$0.72	$3.61	$5.02	$0.00	$0.00	$0.00	$0.00
2020	$10.37	$0.80	$4.00	$5.57	$0.00	$0.00	$0.00	$0.00

Average certification program costs. Based on data obtained from industry, this analysis assumes the following average certification program costs: 1) 9g, $182,000, 2) partial 16g, $227,500, and 3) full 16g, $253,500.[25]

Baseline flight attendant seat certification program costs. Table III.5 shows the resulting baseline estimate of flight attendant seat certification program costs over time. Note that replacement seat costs are assumed to be zero in the baseline. This follows from the assumption that no flight attendant seats are ever replaced; that is, they are assumed to last the life of the airframe.

[25] Presentation by AMI Aircraft Seat Systems dated December 7, 1998. According to industry representatives, significant cost savings—on the order of one-order of magnitude—would result if floor tracks and wall fittings were excluded from the full 16g test requirement for retrofitted flight attendant seats. This follows since, it will be difficult to find, say, a representative test wall for a specific seat installation in a specific airplane to be retrofitted (taking the wall from the subject airplane is impossible since the test is destructive).

2. Flight Attendant Seat Installation Costs

Incremental installation costs arise because seats that by assumption would never be replaced, are replaced either during the mandatory retrofit period (specified under option 3), or during the replacement of passenger seats (under options 4 and 5). Following the 1998 regulatory evaluation, this analysis assumes an average replacement cost of $85 per flight attendant seat.[26] Incremental installation costs associated with each option are discussed below.

3. Flight Attendant Seat Early Replacement Costs

The average cost of a replacement flight attendant seat is estimated at approximately $5,400 (again, following the 1998 regulatory evaluation).[27] Total incremental seat costs associated with early replacement are discussed below.

4. Flight Attendant Seat Weight Penalty

Based on a rough analysis of air carrier aircraft operating statistics, this analysis estimates that a typical part 121 airplane logs about 2,421 flight hours per year. Using data compiled in a study of aircraft fuel consumption by the Washington Consulting Group (footnote 29), the incremental per pound/hour increase in fuel consumption is approximately 5.789×10^{-3} gallons. A three pound increase, then, yields an average annual increase in fuel consumption of approximately:

$$(5.789 \times 10^{-3}) \times 2{,}421 \times 3 = 42.05 \text{ gallons/year/aircraft flight attendant seat}$$

Following the methodology outlined in the 1998 regulatory evaluation (and consistent with information subsequently received from industry), this analysis assumes that the incremental weight impact of bulkhead mounted 16g flight attendant seats is negligible. On the other hand, it is assumed that there is a three pound increase in weight associated with floor mounted 16g flight attendant seats.[28] Table III.6 summarizes the estimated weight penalties associated with 16g flight attendant seats.

As in the case of benefits, operating costs are computed over the service life of the seat. Seat life is assumed to be 42 years for a cabin attendant seat installed in a newly manufactured airplane.

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[26] "According to airplane seat manufacturers, the cost of installing 9g and 16g seats is the same. Based on information received from manufacturers, FAA estimates that it costs approximately $65 to install a passenger seat…and either $65 or $130 to install each flight attendant seat, depending on whether the seat is bulkhead or floor mounted. Approximately 79 percent of all flight attendant seats are bulkhead mounted, while the remaining 30 percent are floor mounted, resulting in a weighted average installation cost of $85 for all flight attendant seats." Muckle, Archie, *Regulatory Evaluation..*, *op. cit.*, p 23.

[27] "…the average cost of a 16g flight attendant seat is $5,400,…" *Ibid.*, p 24.

[28] "Bulkhead-mounted flight attendant seats are lighter and considered to be closer in conformity with 16g seats than floor-mounted flight attendant seats. Only floor-mounted seats, which account for about 30 percent of all flight attendant seats, will be heavier than the 9g seats they replace." Muckle, Archie, *Regulatory Evaluation..*, *op. cit.*, p 23.

(See section II.B.2. The airplane service life assumption is taken from the 1998 Regulatory Evaluation.). Therefore, lifecycle weight penalty costs associated with a new full 16g seat (relative to a 9g seat) can be expressed as:

$$42 \times \$7.27 \approx \$305$$

Discounted weight costs for a seat installed in 2000 (the discounting base period) can be expressed as:

$$\sum_{i=1}^{42}\left(\frac{\$7.27}{1.07^{i-1}}\right)$$

(Discounted costs for a seat installed in year x > 2000 equal the above expression multiplied by $[1.07^{-(x-2000)}]$.)

Table III.6: Estimated Incremental Fuel Consumption
(Cost per year per affected aircraft)[29]

Flight Hours per year	
Hours (Table 18 FAA Forecast)	13,583,000
Aircraft (Table 17)	5,610
Average hours/aircraft	2,421
Gallons/Hour/Pound (10E-03)	5.789
Pound Increase	3
Fuel Price (2000 Dollars Table 7)	0.576
Gallons/Year/Aircraft	42.05
Percent of floor mounted seats	0.30
Avg. Cost/Year/Aircraft FA Seat	$7.27

Assuming that floor mounted seats constitute about 30% percent of flight attendant seat installations, the weighted average and assuming that the price of fuel (for commercial air carriers) is $0.576, the average annual cost per aircraft is $7.27.[30]

[29] Sources: Table 18, *FAA Aerospace Forecasts*, 1999-2010; Washington Consulting Group, *Impact of Weight Changes on Aircraft Fuel Consumption*, January 12, 1994 (2-engine narrow body, 0-50 pounds incremental weight).

[30] The 54% estimate is based on information supplied by AMI Aircraft Seating Systems and includes floor mounted seats and "special" mountings. Note that this assumption is at variance with the 1998 regulatory evaluation which estimated that only 30 percent of seats were floor mounted.

IV. Analysis of Option 1

Option 1 would require no regulatory action. Instead the FAA would continue to track the industry, monitoring such developments as: 1) the types of seats that are installed in the future, 2) the degree to which new derivative models incorporate 16g features, 3) the rate at which new type certificates are introduced, and 4) the rate at which older airplane models are retired.

A. The Case For Option 1

A case for Option 1 can be expressed in terms of three of the four decision factors.

1. Factor 1: Projected Accident/Casualty Rates

Although there are some safety benefits associated with full 16g and partial 16g seats, a decision not to take any further regulatory action is justified because the likelihood of accidents is declining and will continue to decline as a result of recent regulations and new safety initiatives adopted in the future.

2. Factor 2: Future Distribution of Seat Types

Even if one assumes a constant or increasing accident rate, the industry will continue to replace older seats with full 16g and partial 16g seats voluntarily in the future. According to industry officials, most seats manufactured and installed today would probably pass a "16g-compatibility" test (i.e. withstand the required structural loads). Few "9g" seats are made and "9g" certifications constitute less than 2% of total certifications.

3. Factor 4: Net Costs

A new regulation would significantly increase costs (particularly the costs associated with certifying that the new seats are compliant). Given the above, there would be very little corresponding increase in the actual performance of the seat.

B. The Case Against Option 1

1. Factor 1: Projected Accident/Casualty Rates

There is no guarantee that accident/casualty rates will continue to decline in the future. Moreover, it is not necessarily true that additional future safety regulations will reduce the need for 16g seats. For example, if the likelihood of a post-crash fire is high, then 16g seats may not materially affect survival probabilities (i.e., an occupant survives impact but is killed by fire). More stringent fire protection measures in the future, therefore, could synergistically increase the survivability benefits associated with improved seats.

2. Factor 2: Future Distribution of Seat Types

Industry claims notwithstanding, few if any seat installations in Group II and Group III (refer to figure II.2) have been tested to demonstrate actual seat performance. The perceived removal of the threat of FAA action and changing economic conditions may cause operators to revert to 9g replacement seats in the future. Beyond that, industry officials have indicated that certain older in-service airplanes would probably not meet 16g-compatibility requirements regardless of the seats due to their seat tracks and/or floors. In the absence of some type of regulation, these airplanes would most likely never have partial 16g performance. Finally, Option 1 would leave open the possibility that part 121 operators could continue to acquire aircraft from outside the U.S. that have seats that have far less than full or partial 16g performance.

3. Factor 4: Net Costs

The baseline assumptions are conservative with respect to costs (i.e. they embody the high end of the range of most likely cost values). For example, this study assumes that, for a given airplane, every replacement seat installation would require certification testing. It is likely that a new requirement will create incentives to standardize seat designs so as to minimize certification costs.[31]

C. Estimated Benefits of Voluntary Industry Action

Seats installed in passenger airplanes today, for the most part, offer more occupant protection than older generation seats even though (aside from new type certificates) there is no requirement to do so. The analysis anticipates that this trend is likely to continue, and so the benefits for Options 2 through 5 are adjusted to account for voluntary industry action (Option 1). Tables IV.1a and b show the numbers of fatalities and serious injuries averted under the current regime (where partial and full 16g seats are voluntarily installed) compared to a hypothetical condition where all seats are 9g (Group I). These safety benefits are computed on a lifecycle basis as follows:

An estimate of the number of enplanements per seat per year was computed by dividing the projected number of part 121 enplanements in 2000 by the projected number of part 121 seats: 676.9 million divided by 741,498 equals approximately 913.[32] Assuming that the future rates of fatalities and injuries (per million enplanements) are 0.2868 and 0.0436, respectively; then the projected rates of fatalities and injuries per seat per year are, respectively:

$$913 \times (0.2686 \times 10^{-6}) = (261.8 \times 10^{-6})$$

[31] See, for example, *Passenger Seat News: The Newsletter of The Boeing Passenger Seat Group*, Volume 3, Issue 1, February, 2000.

[32] Note that this assumption implies that the number of enplanements per seat per year is constant throughout the service life of the seat. This is a conservative assumption. If load factors increase over time (and if this increased utilization does not affect seat costs or service lives), then, all other factors constant, benefit-cost will increase.

$$913 \times (0.0436 \times 10^{-6}) = (39.8 \times 10^{-6})$$

These rates represent hypothetical estimates of future casualties given that all seats are 9g. Based on the Cherry analysis (see Section II), this study estimates that 16g seats will reduce fatalities and serious injuries by approximately 3.1% and 24.0%, respectively (relative to 9g seats). In other words, 16g seats will avert:

$0.0314 \times (261.8 \times 10^{-6}) = (8.23 \times 10^{-6})$ fatalities per seat per year, and

$0.2401 \times (39.8 \times 10^{-6}) = (9.56 \times 10^{-6})$ serious injuries per seat per year.

As noted earlier, these estimates represent the maximum safety benefits that are theoretically possible if 9g seats are replaced with full 16g (Group V) seats. Benefits for other seat types are estimated by applying the factors discussed in Section II (see Table II.11). The dollar estimates of averted casualties are computed by applying FAA life and serious injury valuations ($2.7 million and $500,000, respectively). In symbols:

N = the number of enplanements per seat per year (assumed constant)

C = the casualty rate (fatalities or serious injuries) per million enplanements (assumed constant)

$N \times C$ = the number of casualties per seat per year multiplied by 10^6 (a baseline estimate of 9g seat performance)

R = the percentage reduction in casualties associated with 16g seats as compared to 9g seats

f_i = the effectiveness factor of each seat type

$((N \times C) \times R) \times f_i \times 14 \times 10^{-6}$ = the expected number of lifecycle casualties averted per seat given a seat of Group "i" compared to a Group I 9g seat

S_{ito} = the number of Group "i" seats installed in year "t" under option "o" ("i" ranges from Group I to Group V, "t" ranges from 2000 to 2020, and "o" ranges from option 1 to option 5)

$\sum_i [((N \times C) \times R) \times f_i \times 14 \times 10^{-6}] \times S_{ito}$ = the expected number of lifecycle casualties averted for all seats (Groups II-V) installed in year "t" under option "o"

Table IV.1a: Baseline Projected Lifecycle Fatalities Averted
Option 1 (Voluntary Industry Action) Relative to Hypothetical 9g Fleet

	Seats in Newly Manufactured Airplanes					Replacement Seats					Total				
Seats Installed in Year...	Total	Group II	Group III	Group IV	Group V	Total	Group II	Group III	Group IV	Group V	Total	Group II	Group III	Group IV	Group V
2000	2.1	0.0	0.1	0.6	1.5	0.4	0.4	0.0	0.0	0.0	2.5	0.4	0.1	0.6	1.5
2001	2.5	0.0	0.1	0.7	1.7	0.5	0.5	0.0	0.0	0.0	3.0	0.5	0.1	0.7	1.7
2002	2.7	0.0	0.1	0.8	1.9	0.6	0.5	0.1	0.0	0.0	3.3	0.5	0.2	0.8	1.9
2003	3.1	0.0	0.1	0.9	2.2	0.6	0.5	0.2	0.0	0.0	3.7	0.5	0.3	0.9	2.2
2004	3.0	0.0	0.1	0.8	2.1	0.7	0.4	0.2	0.0	0.0	3.7	0.4	0.3	0.8	2.1
2005	3.8	0.0	0.1	1.1	2.7	0.7	0.4	0.3	0.0	0.0	4.5	0.4	0.4	1.1	2.7
2006	3.4	0.0	0.1	0.9	2.4	0.7	0.4	0.3	0.0	0.0	4.1	0.4	0.4	0.9	2.4
2007	3.9	0.0	0.1	1.1	2.7	0.8	0.4	0.4	0.0	0.0	4.6	0.4	0.5	1.1	2.7
2008	4.0	0.0	0.1	1.1	2.8	0.8	0.4	0.5	0.0	0.0	4.8	0.4	0.6	1.1	2.8
2009	4.3	0.0	0.1	1.2	3.0	1.0	0.3	0.5	0.1	0.2	5.3	0.3	0.6	1.3	3.1
2010	5.0	0.0	0.1	1.4	3.5	1.2	0.3	0.5	0.1	0.3	6.2	0.3	0.6	1.5	3.8
2011	5.3	0.0	0.1	1.5	3.7	1.4	0.3	0.4	0.2	0.5	6.7	0.3	0.5	1.7	4.2
2012	5.5	0.0	0.2	1.5	3.8	1.7	0.3	0.3	0.3	0.7	7.2	0.3	0.5	1.8	4.6
2013	5.4	0.0	0.1	1.5	3.7	2.0	0.4	0.3	0.4	1.0	7.4	0.4	0.4	1.9	4.7
2014	5.5	0.0	0.2	1.5	3.8	2.3	0.4	0.3	0.5	1.2	7.8	0.4	0.4	2.0	5.0
2015	6.2	0.0	0.2	1.7	4.3	2.8	0.4	0.3	0.6	1.5	9.0	0.4	0.5	2.3	5.8
2016	6.7	0.0	0.2	1.9	4.6	3.1	0.4	0.3	0.7	1.7	9.8	0.4	0.5	2.6	6.4
2017	7.0	0.0	0.2	2.0	4.9	3.5	0.4	0.2	0.8	2.0	10.5	0.4	0.4	2.8	6.9
2018	7.1	0.0	0.2	2.0	4.9	3.7	0.4	0.3	0.9	2.2	10.8	0.4	0.5	2.8	7.1
2019	7.0	0.0	0.2	1.9	4.8	4.0	0.3	0.4	1.0	2.4	11.0	0.3	0.6	2.9	7.2
2020	7.7	0.0	0.2	2.1	5.4	4.4	0.3	0.4	1.0	2.6	12.1	0.3	0.6	3.2	8.0

It is important to note that these represent lifecycle benefits. For example, over the service lives of Group II-V seats installed in newly manufactured airplanes in the year 2000 (the gray shaded box in the table), approximately 2.1 fatalities would be averted.

Table IV.1b: Baseline Projected Lifecycle Serious Injuries Averted (Net)
Option 1 (Voluntary Industry Action) Relative to Hypothetical 9g Fleet

	Seats in Newly Manufactured Airplanes					Replacement Seats					Total				
Seats Installed in Year...	Total	Group II	Group III	Group IV	Group V	Total	Group II	Group III	Group IV	Group V	Total	Group II	Group III	Group IV	Group V
2000	2.5	0.0	0.1	0.7	1.7	0.5	0.5	0.0	0.0	0.0	2.9	0.5	0.1	0.7	1.7
2001	2.9	0.0	0.1	0.8	2.0	0.5	0.5	0.0	0.0	0.0	3.5	0.5	0.1	0.8	2.0
2002	3.2	0.0	0.1	0.9	2.2	0.7	0.5	0.1	0.0	0.0	3.8	0.5	0.2	0.9	2.2
2003	3.6	0.0	0.1	1.0	2.5	0.8	0.5	0.2	0.0	0.0	4.4	0.5	0.3	1.0	2.5
2004	3.5	0.0	0.1	1.0	2.4	0.8	0.5	0.3	0.0	0.0	4.3	0.5	0.4	1.0	2.4
2005	4.5	0.0	0.1	1.2	3.1	0.8	0.5	0.3	0.0	0.0	5.3	0.5	0.4	1.2	3.1
2006	4.0	0.0	0.1	1.1	2.7	0.8	0.5	0.4	0.0	0.0	4.8	0.5	0.5	1.1	2.7
2007	4.5	0.0	0.1	1.2	3.1	0.9	0.4	0.4	0.0	0.0	5.4	0.4	0.6	1.2	3.1
2008	4.7	0.0	0.1	1.3	3.2	1.0	0.4	0.5	0.0	0.0	5.6	0.4	0.7	1.3	3.2
2009	5.0	0.0	0.1	1.4	3.5	1.2	0.4	0.5	0.1	0.2	6.2	0.4	0.7	1.5	3.6
2010	5.8	0.0	0.2	1.6	4.1	1.4	0.4	0.5	0.1	0.4	7.2	0.4	0.7	1.8	4.4
2011	6.2	0.0	0.2	1.7	4.3	1.6	0.4	0.4	0.2	0.6	7.8	0.4	0.6	2.0	4.9
2012	6.4	0.0	0.2	1.8	4.5	1.9	0.4	0.4	0.3	0.8	8.4	0.4	0.5	2.1	5.3
2013	6.3	0.0	0.2	1.7	4.3	2.3	0.4	0.3	0.4	1.1	8.6	0.4	0.5	2.2	5.5
2014	6.4	0.0	0.2	1.8	4.4	2.7	0.4	0.3	0.6	1.4	9.1	0.4	0.5	2.3	5.8
2015	7.2	0.0	0.2	2.0	5.0	3.2	0.4	0.3	0.7	1.7	10.4	0.4	0.5	2.7	6.7
2016	7.8	0.0	0.2	2.2	5.4	3.6	0.4	0.3	0.8	2.0	11.4	0.4	0.5	3.0	7.4
2017	8.2	0.0	0.2	2.3	5.7	4.0	0.4	0.3	1.0	2.4	12.2	0.4	0.5	3.2	8.1
2018	8.2	0.0	0.2	2.3	5.7	4.3	0.4	0.4	1.0	2.6	12.5	0.4	0.6	3.3	8.3
2019	8.1	0.0	0.2	2.2	5.6	4.7	0.4	0.4	1.1	2.8	12.8	0.4	0.6	3.4	8.4
2020	9.0	0.0	0.2	2.5	6.2	5.1	0.4	0.5	1.2	3.0	14.1	0.4	0.7	3.7	9.3

It is important to note that these represent lifecycle benefits. For example, over the service lives of Group II-V seats installed in newly manufactured airplanes in the year 2000 (the gray shaded box in the table), approximately 2.5 serious injuries (net) would be averted.

V. Analysis of Option 2

Option 2 would require that, after 2004, all newly manufactured transport category airplanes operating under 14 CFR part 121 comply with the requirements of 14 CFR §25.562 (a), (b), and (c). This option is assessed in terms of the four decision factors.

A. Factor 1: Baseline Accident/Casualty Rates

This study assumes that the fatality and serious injury rates for the period 2000-2020 will be 0.2868 and 0.0436 per million enplanements, respectively. (These estimates were derived from historical fatality/serious injury and enplanement data for U.S. part 121 operators during 1984-1998. See Table II.3, Section II.)

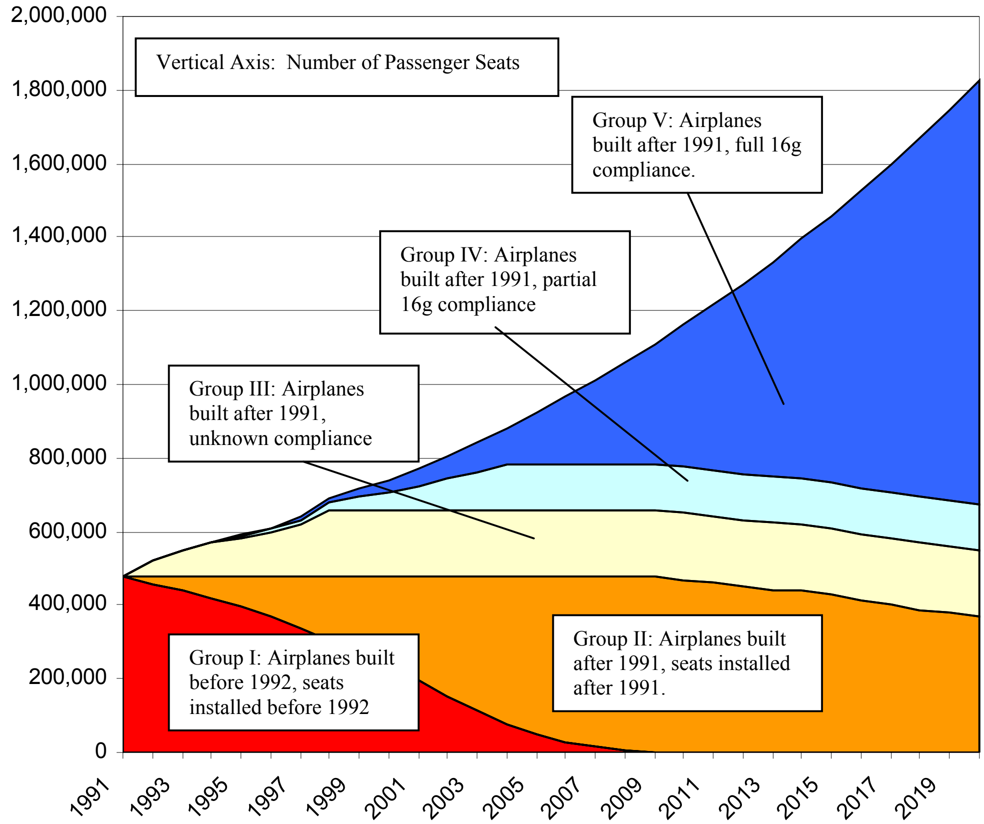
B. Factor 2: Future Distribution of Seat Types

The impact of this requirement on the distribution of seats is shown in Figure V.1 and Table V.1. The projected distribution assumes that manufacturers have approximately 5 years to comply with the rule (2005 compliance date). Less-than-full 16g seats would be entirely phased out of the part 121 fleet within 50 years.

Table V.1: Projected Distribution of Seat Types Under Option 2

	Group I	Group II	Group III	Group IV	Group V
1999	272,720	205,271	178,598	36,534	22,960
2000	235,773	242,218	178,852	50,512	34,143
2001	194,919	283,072	179,154	67,114	47,424
2002	154,523	323,304	179,483	85,209	61,900
2003	115,007	362,820	179,857	105,771	78,349
2004	77,682	400,025	180,218	125,642	94,246
2005	46,440	431,215	180,218	125,642	140,434
2006	26,910	450,745	180,218	125,642	181,503
2007	13,760	463,791	180,218	125,642	228,023
2008	4,650	472,531	180,218	125,642	276,269
2009	0	476,011	180,218	125,642	327,892
2010	0	469,770	180,218	125,642	388,404
2011	0	459,375	180,218	125,642	452,496
2012	0	448,921	180,218	125,642	519,124
2013	0	442,791	180,218	125,642	584,019
2014	0	437,926	180,218	125,642	650,359
2015	0	427,412	180,218	125,642	725,185
2016	0	414,061	180,218	125,642	805,814
2017	0	399,673	180,218	125,642	890,584
2018	0	388,254	180,218	125,642	975,631
2019	0	381,358	180,218	125,642	1,059,552
2020	0	368,871	180,218	125,642	1,152,618

Figure V.1: Option 2. Full Compliance with 14 CFR §25.562 After 2005
For Newly Manufactured Transport Category Airplanes Operating Under Part 121



C. Factor 3: Performance of Full 16g Seats Relative to Partial 16g Seats and 9g Seats

In general, calculation of averted fatalities and serious injuries associated with Option 2 follows the methodology described in Section IV.[33] *However, Option 2 safety benefits must be adjusted to account for the reduction in casualties that are associated with voluntary industry action.* For example, using the symbology developed in the previous section, the lifecycle safety benefits associated with Group II seats installed in year "t" under Option 2 equal:

$$[((N \times C) \times R) \times f_{(Group\ II)} \times 14 \times 10^{-6}] \times S_{(Group\ II)t(Option\ 2)} \text{ minus}$$

$$[((N \times C) \times R) \times f_{(Group\ II)} \times 14 \times 10^{-6}] \times S_{(Group\ II)t(Option\ 1)}, \text{ or}$$

$$[((N \times C) \times R) \times f_{(Group\ II)} \times 14 \times 10^{-6}] \times [S_{(Group\ II)t(Option\ 2)} - S_{(Group\ II)t(Option\ 1)}]$$

The expected undiscounted value of lifecycle benefits associated with Group II seats installed in year "t" under Option 2 is given by:

$$[((N \times C) \times R) \times f_{(Group\ II)} \times 14 \times V \times 10^{-6}] \times [S_{(Group\ II)t(Option\ 2)} - S_{(Group\ II)t(Option\ 1)}]$$

Where V equals the value of a casualty averted—$2.7 million for a fatality, or $0.5 million for a serious injury. Expected discounted lifecycle benefits for Group II seats (for seats installed in t = 2000) are computed by:

$$\sum_y [(((N \times C) \times R) \times f_{(Group\ II)}) \times V \times 10^{-6}] \times [S_{(Group\ II)t(Option\ 2)} - S_{(Group\ II)t(Option\ 1)}] \div (1.07^{(y-1)})$$

where y is an index for the range of seat life. (Discounted per seat lifecycle benefits for seats installed in year Y>2000 are computed by multiplying the above expression by $1.07^{-(Y-2000)}$.) In words, these equations show that the net benefits of Option "i" depend only the degree to which the distribution of seat types under Option "i" differs from the Option 1 seat distribution:

$$[S_{(Group\ II)t(Option\ \text{“i”})} - S_{(Group\ II)t(Option\ 1)}]$$

Tables V.2 and V.3 show fatalities and injuries averted under Option 2 relative to Option 1.

[33] In this analysis, the ratio of passenger to flight attendant fatalities is assumed to be 98:2 (following the assumed proportion of flight attendant seats from the 1998 regulatory evaluation). A more detailed study of the relative benefits of passenger versus flight attendant seats would involve: 1) going back to the NTSB accident data to determine the numbers of passenger and flight attendant fatalities, and 2) deriving a measure of "flight attendant enplanements" equivalent to passenger enplanements.

Table V.2: Projected Lifecycle Fatalities Averted Under Option 2
By Year of Seat Installation

	Fatalities Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	**Group II**	**Group III**	**Group IV**	**Group V**	**Total**	**Relative to Option 1**
2000	2.5	0.4	0.1	0.6	1.5	0.0
2001	3.0	0.5	0.1	0.7	1.7	0.0
2002	3.3	0.5	0.2	0.8	1.9	0.0
2003	3.7	0.5	0.3	0.9	2.2	0.0
2004	3.7	0.4	0.3	0.8	2.1	0.0
2005	6.0	0.4	0.3	0.0	5.3	1.5
2006	5.5	0.4	0.3	0.0	4.7	1.3
2007	6.1	0.4	0.4	0.0	5.4	1.5
2008	6.4	0.4	0.5	0.0	5.6	1.6
2009	7.0	0.3	0.5	0.1	6.1	1.7
2010	8.2	0.3	0.5	0.1	7.3	2.0
2011	8.8	0.3	0.4	0.2	7.9	2.1
2012	9.3	0.3	0.3	0.3	8.4	2.2
2013	9.5	0.4	0.3	0.4	8.4	2.1
2014	10.0	0.4	0.3	0.5	8.8	2.1
2015	11.4	0.4	0.3	0.6	10.1	2.4
2016	12.4	0.4	0.3	0.7	11.0	2.6
2017	13.2	0.4	0.2	0.8	11.8	2.7
2018	13.5	0.4	0.3	0.9	12.0	2.7
2019	13.7	0.3	0.4	1.0	12.1	2.7
2020	15.1	0.3	0.4	1.0	13.3	3.0

Table V.3: Projected Lifecycle Serious Injuries Averted Under Option 2
By Year of Seat Installation

	Serious Injuries Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	**Group II**	**Group III**	**Group IV**	**Group V**	**Total**	**Relative to Option 1**
2000	2.9	0.5	0.1	0.7	1.7	0.0
2001	3.5	0.5	0.1	0.8	2.0	0.0
2002	3.8	0.5	0.2	0.9	2.2	0.0
2003	4.4	0.5	0.3	1.0	2.5	0.0
2004	4.3	0.5	0.4	1.0	2.4	0.0
2005	7.0	0.5	0.3	0.0	6.2	1.7
2006	6.3	0.5	0.4	0.0	5.5	1.5
2007	7.1	0.4	0.4	0.0	6.2	1.7
2008	7.4	0.4	0.5	0.0	6.5	1.8
2009	8.1	0.4	0.5	0.1	7.1	1.9
2010	9.5	0.4	0.5	0.1	8.5	2.3
2011	10.2	0.4	0.4	0.2	9.2	2.4
2012	10.8	0.4	0.4	0.3	9.8	2.5
2013	11.0	0.4	0.3	0.4	9.8	2.4
2014	11.6	0.4	0.3	0.6	10.3	2.5
2015	13.2	0.4	0.3	0.7	11.7	2.8
2016	14.4	0.4	0.3	0.8	12.8	3.0
2017	15.4	0.4	0.3	1.0	13.7	3.2
2018	15.7	0.4	0.4	1.0	13.9	3.2
2019	15.9	0.4	0.4	1.1	14.0	3.1
2020	17.6	0.4	0.5	1.2	15.5	3.5

As noted elsewhere in this report, the figures above refer to serious injuries only. The *Cherry Benefits Analysis* of serious injuries reflects the net effect of two factors: 1) the decrease in injuries that results from improved passenger protection, and 2) the *increase* in injuries that results from averting fatalities. The second factor follows from the Cherry methodology—16g impact survivors (who would have otherwise been killed by impact in a 9g seat) could: 1) perish due to a subsequent post-crash fire, 2) become seriously injured in a post-crash fire, or 3) survive unharmed by either the impact or a post-crash fire.

It is important to note that Figure V.1 and Tables V.2 and V.3 do not account for used foreign aircraft (see also the discussion in Section IV). A requirement that only affects newly produced aircraft intended for sale to 14 CFR part 121 operators, would leave open the possibility that used 9g airplanes could still be acquired from foreign countries that did not require 16g seats.

Table V.4: Value of Lifecycle Casualties Averted By Year of Seat Installation
Option 2 Relative to Option 1 (Voluntary Industry Action)
($2.7 million per fatality, $0.5 million per serious injury, 7.0% discount rate, 2000 base year)

Seats Installed in Year…	Fatalities Averted	Injuries Averted	Undiscounted Dollars	Discounted Dollars
2000	0.0	0.0	$0.0	$0.0
2001	0.0	0.0	$0.0	$0.0
2002	0.0	0.0	$0.0	$0.0
2003	0.0	0.0	$0.0	$0.0
2004	0.0	0.0	$0.0	$0.0
2005	1.5	1.7	$4.9	$2.6
2006	1.3	1.5	$4.3	$2.2
2007	1.5	1.7	$4.9	$2.3
2008	1.6	1.8	$5.1	$2.2
2009	1.7	1.9	$5.5	$2.2
2010	2.0	2.3	$6.4	$2.4
2011	2.1	2.4	$6.8	$2.4
2012	2.2	2.5	$7.1	$2.3
2013	2.1	2.4	$6.9	$2.1
2014	2.1	2.5	$7.0	$2.0
2015	2.4	2.8	$7.9	$2.2
2016	2.6	3.0	$8.5	$2.2
2017	2.7	3.2	$9.0	$2.1
2018	2.7	3.2	$9.0	$2.0
2019	2.7	3.1	$8.9	$1.8
2020	3.0	3.5	$9.9	$1.9
Total	34.2	39.7	$112.1	$35.1

The benefits estimates computed above apply to passengers and cabin attendants. Under the assumption that cabin attendants represent approximately 2% of occupants (and assuming that the ratio of passenger/attendant benefits are roughly proportional), this analysis estimates that the benefit that accrues to the passenger seat requirement is approximately $112.1 million × .98 = $109.8 million (or $34.4 million at present value). Similarly, the estimated benefit to the cabin attendant seat requirement is approximately $2.2 million (or $0.7 million at present value).

D. Factor 4: Net Costs

1. Passenger Seats

Since this option only affects newly manufactured airplanes, there are no incremental costs associated with prematurely replaced passenger seats, installation, or downtime. In addition, based on industry data, this analysis assumes that there is little or no weight penalty associated with full 16g seats. According to industry representatives, it is difficult to estimate the difference in weight attributable to the 16g requirement. One manufacturer reported that it sells very few 9g seats; almost all customers purchase the same seats whether or not they require 16g compatibility. According to these sources, the increase in weight related to 16g is negligible when compared to the weight introduced by features added to increase passenger utility (e.g. entertainment systems, back support systems, etc.). In addition, there are no differences in maintenance costs between 9g and 16g seats. It is possible, in fact, that 16g seats may actually last longer and, therefore, require less frequent replacement.

The distribution of certification programs for newly manufactured airplanes, however, will change: under Option 2 all new seat certification programs will be full 16g after 2004. This redistribution of certification programs is estimated to increase passenger seat certification costs by approximately $70.7 million for seats installed during the forecast period 2000-2020. The calculations are shown in Table V.5; undiscounted and discounted incremental certification costs (i.e. the difference in certification costs under Option 2 relative to Option 1).

Table V.5: Incremental Passenger Seat Certification Costs Under Option 2
(Millions of undiscounted and discounted dollars, 2000 base year.)

Year	Undiscounted	Discounted
2000	$0.0	$0.0
2001	$0.0	$0.0
2002	$0.0	$0.0
2003	$0.0	$0.0
2004	$0.0	$0.0
2005	$3.1	$2.2
2006	$2.7	$1.8
2007	$3.1	$1.9
2008	$3.2	$1.9
2009	$3.4	$1.9
2010	$4.0	$2.1
2011	$4.3	$2.0
2012	$4.5	$2.0
2013	$4.3	$1.8
2014	$4.4	$1.7
2015	$5.0	$1.8
2016	$5.4	$1.8
2017	$5.7	$1.8
2018	$5.7	$1.7
2019	$5.6	$1.6
2020	$6.2	$1.6
Total	$70.7	$29.6

2. Flight Attendant Seat Costs

Certification costs. As in the case of passenger seats, flight attendant seat costs increase as certification testing shifts from 9g or partial 16g programs to full 16g programs. The computations are summarized in Table V.6.

Seat cost and installation. The 1998 regulatory evaluation reported a small incremental difference between 9g and 16g flight attendant seats—approximately 5% on the cost of a $5,140 flight attendant seat. However, this analysis assumes that the incremental cost of a 16g flight attendant seat *under option 2* is negligible based on discussions with industry, the increasing percentage of "partial 16g" seats, and potential reductions in unit costs that would accompany increasing production of 16g seats.

Table V.6: Incremental Flight Attendant Seat Certification Costs Under Option 2
(Millions of undiscounted and discounted dollars, 2000 base year.)

Year	Undiscounted	Discounted
2000	$0.0	$0.0
2001	$0.0	$0.0
2002	$0.0	$0.0
2003	$0.0	$0.0
2004	$0.0	$0.0
2005	$0.4	$0.3
2006	$0.3	$0.2
2007	$0.4	$0.2
2008	$0.4	$0.2
2009	$0.4	$0.2
2010	$0.5	$0.3
2011	$0.5	$0.3
2012	$0.6	$0.2
2013	$0.5	$0.2
2014	$0.5	$0.2
2015	$0.6	$0.2
2016	$0.7	$0.2
2017	$0.7	$0.2
2018	$0.7	$0.2
2019	$0.7	$0.2
2020	$0.8	$0.2
Total	$8.8	$3.7

Weight. As noted in Section III, the weight penalty for flight attendant seats is computed over the expected service life of the seat (42 years for a seat installed in a newly manufactured airplane). The calculations are shown in Table V.7. It is important to emphasize that these are lifecycle calculations. For example, in the column "Undiscounted Costs—New Installations," the cell for the year "2005" represents incremental lifecycle weight costs for all seats installed in new airplanes in the year 2005.

E. Benefit-Cost Comparison: Option 2

In total, Option 2 would avert approximately 34.2 fatalities and 39.7 serious injuries—these are the lifecycle averted casualties associated with seats installed during the forecast period. Assuming $2.7 million per fatality averted and $0.5 million per serious injury averted, this is equivalent to a benefit of $112.1 million, or $35.1 million at present value (2000 dollars). Option 2 is estimated to cost approximately $82.7 million in undiscounted dollars, or $33.7 million at present value (2000 base year). In undiscounted dollars, Option 2 would cost approximately $2.42 million per fatality averted. The discounted benefit-cost ratio of this option is approximately 1.042.

Considering only passenger benefits and costs, the discounted benefit cost ratio of this option is approximately 1.164. Because this option would only affect newly manufactured airplanes, its effect on cabin attendant seats is minimal: Option 2 would increase cabin attendant seat costs (again, for seats installed during the forecast period) by about $12.0 million, or $4.1 million at present value.

Table V.7: Lifecycle Flight Attendant Seat Weight Costs Under Option 2
By Year of Seat Installation
(Millions of undiscounted and discounted dollars, 2000 base year.)

	Undiscounted Weight Costs			**Discounted Weight Costs**		
Seats Installed in Year…	**New Installations**	**Replacement Installations**	**Total**	**New Installations**	**Replacement Installations**	**Total**
2000	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2001	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2002	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2003	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2004	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2005	$0.14	$0.00	$0.14	$0.03	$0.00	$0.03
2006	$0.13	$0.00	$0.13	$0.03	$0.00	$0.03
2007	$0.14	$0.00	$0.14	$0.03	$0.00	$0.03
2008	$0.15	$0.00	$0.15	$0.03	$0.00	$0.03
2009	$0.16	$0.00	$0.16	$0.03	$0.00	$0.03
2010	$0.18	$0.00	$0.18	$0.03	$0.00	$0.03
2011	$0.20	$0.00	$0.20	$0.03	$0.00	$0.03
2012	$0.20	$0.00	$0.20	$0.03	$0.00	$0.03
2013	$0.20	$0.00	$0.20	$0.03	$0.00	$0.03
2014	$0.20	$0.00	$0.20	$0.03	$0.00	$0.03
2015	$0.23	$0.00	$0.23	$0.03	$0.00	$0.03
2016	$0.25	$0.00	$0.25	$0.03	$0.00	$0.03
2017	$0.26	$0.00	$0.26	$0.03	$0.00	$0.03
2018	$0.26	$0.00	$0.26	$0.03	$0.00	$0.03
2019	$0.26	$0.00	$0.26	$0.02	$0.00	$0.02
2020	$0.28	$0.00	$0.28	$0.03	$0.00	$0.03
Total	**$3.23**	**$0.00**	**$3.23**	**$0.46**	**$0.00**	**$0.46**

VI. Analysis of Option 3

Option 3 would require that, after 2004, all newly manufactured transport category airplanes operating under 14 CFR part 121 comply with the requirements of 14 CFR part 25.562 (a), (b), and (c). In addition, this option would require that all passenger seats in in-service airplanes be replaced with seats that meet TSO-C127a (minus HIC) by 2007.

A. Factor 1: Baseline Accident/Casualty Rates

As discussed above, this study assumes that the baseline fatality and serious injury rates for the period 2000-2020 will be 0.2868 and 0.0436 per million enplanements, respectively. (See Section II.)

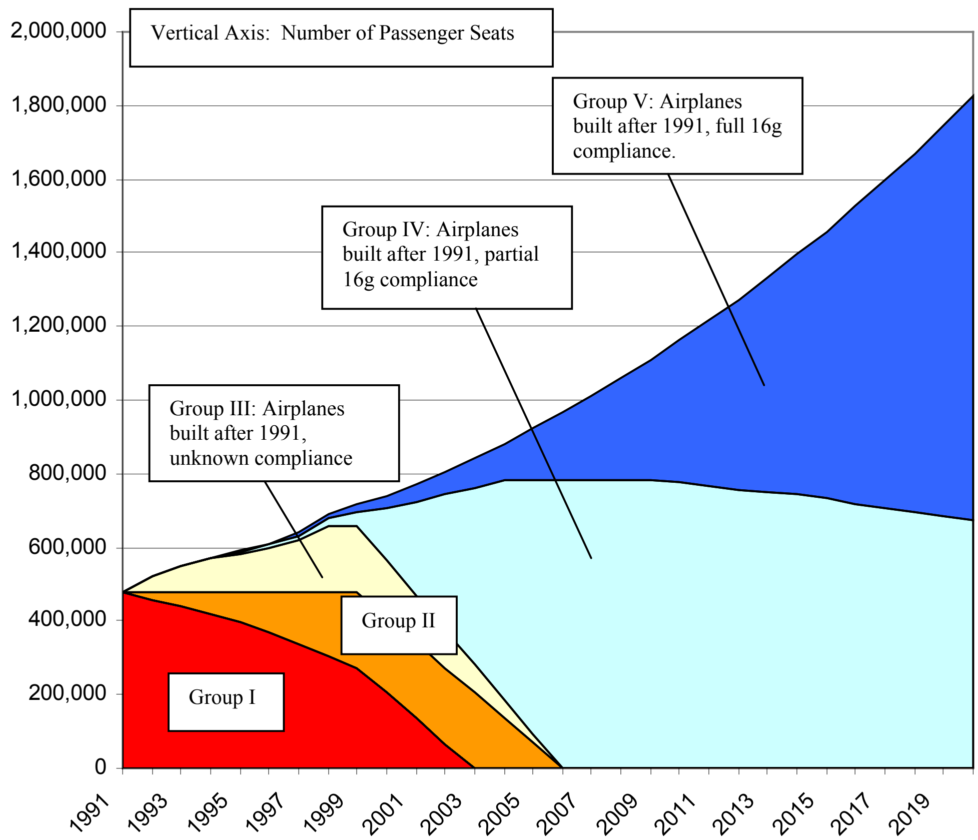
B. Factor 2: Future Distribution of Seat Types

The impact of this requirement on the distribution of seats is shown in Figure VI.1 and Table VI.1. The projected distribution assumes that manufacturers have approximately 5 years to comply with the rule (2005 compliance date). Less-than-full 16g seats would be entirely phased out of the part 121 fleet within 50 years.

Table VI.1: Projected Distribution of Seat Types Under Option 3

	Group I	Group II	Group III	Group IV	Group V
2000	204,436	205,271	153,084	144,565	34,143
2001	136,151	205,271	127,570	255,267	47,424
2002	67,867	205,107	102,056	367,490	61,900
2003	0	204,689	76,542	482,223	78,349
2004	0	136,285	51,028	596,254	94,246
2005	0	67,948	25,514	690,052	140,434
2006	0	0	0	783,515	181,503
2007	0	0	0	783,411	228,023
2008	0	0	0	783,041	276,269
2009	0	0	0	781,871	327,892
2010	0	0	0	775,630	388,404
2011	0	0	0	765,235	452,496
2012	0	0	0	754,781	519,124
2013	0	0	0	748,651	584,019
2014	0	0	0	743,786	650,359
2015	0	0	0	733,272	725,185
2016	0	0	0	719,921	805,814
2017	0	0	0	705,533	890,584
2018	0	0	0	694,114	975,631
2019	0	0	0	687,218	1,059,552
2020	0	0	0	674,731	1,152,618

Figure VI.1: Option 3. Full Compliance with 14 CFR §25.562 After 2005
For Newly Manufactured Transport Category Airplanes Operating Under Part 121
Plus Retrofit (TSO-C127a Without HIC) of In-Service Part 121 Airplanes by 2007



C. Factor 3: Performance of Full 16g Seats Relative to Partial 16g Seats and 9g Seats

The projected numbers of fatalities and injuries averted under Option 3 are computed following the process outlined in Section II; the results are shown in Tables VI.2 and VI.3. Again, these are lifecycle results.

Table VI.2: Projected Lifecycle Fatalities Averted Under Option 3
By Year of Seat Installation

	Fatalities Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	**Group II**	**Group III**	**Group IV**	**Group V**	**Total**	**Relative to Option 1**
2000	0.0	0.0	6.2	1.5	7.6	5.1
2001	0.0	0.0	6.3	1.7	8.0	5.1
2002	0.0	0.0	6.4	1.9	8.3	5.0
2003	0.0	0.0	6.5	2.2	8.7	4.9
2004	0.0	0.0	6.5	2.1	8.5	4.9
2005	0.0	0.0	5.4	5.3	10.7	6.2
2006	0.0	0.0	5.4	4.7	10.1	6.0
2007	0.0	0.0	0.0	5.4	5.4	0.8
2008	0.0	0.0	0.0	5.6	5.6	0.7
2009	0.0	0.0	0.1	6.1	6.2	0.9
2010	0.0	0.0	0.8	7.3	8.1	1.8
2011	0.0	0.0	1.5	7.9	9.4	2.6
2012	0.0	0.0	2.2	8.4	10.6	3.4
2013	0.0	0.0	2.9	8.4	11.3	3.9
2014	0.0	0.0	3.6	8.8	12.4	4.6
2015	0.0	0.0	4.2	10.4	14.6	5.7
2016	0.0	0.0	4.8	11.6	16.4	6.6
2017	0.0	0.0	4.8	12.7	17.5	7.0
2018	0.0	0.0	4.7	13.2	17.9	7.1
2019	0.0	0.0	4.1	13.6	17.6	6.6
2020	0.0	0.0	3.4	15.2	18.6	6.5
Total	0.0	0.0	79.6	153.9	233.5	95.3

The first five columns of each table (labeled "Group II", "Group III", "Group IV", "Group V", and "Total) show the number of casualties averted when various vintages of full or partial 16g seats are compared to a hypothetical state in which all seats are 9g. The last column (labeled "Relative to Option 1") shows the number of casualties averted when Option 3 is compared to Option 1 (which includes credit for voluntary industry action to install full and partial 16g seats).

The estimates of casualties averted are then multiplied by the standard values for fatalities and injuries ($2.7 million and $0.5 million, respectively) to obtain undiscounted benefits estimates. The results are shown in Table IV.4.

Table VI.3: Projected Lifecycle Serious Injuries Averted Under Option 3[34]
By Year of Seat Installation

	Serious Injuries Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	**Group II**	**Group III**	**Group IV**	**Group V**	**Total**	**Relative to Option 1**
2000	0.0	0.0	7.2	1.7	8.9	5.9
2001	0.0	0.0	7.3	2.0	9.3	5.9
2002	0.0	0.0	7.4	2.2	9.6	5.8
2003	0.0	0.0	7.6	2.5	10.1	5.7
2004	0.0	0.0	7.5	2.4	9.9	5.7
2005	0.0	0.0	6.3	6.2	12.5	7.2
2006	0.0	0.0	6.3	5.5	11.8	7.0
2007	0.0	0.0	0.0	6.2	6.2	0.9
2008	0.0	0.0	0.0	6.5	6.5	0.9
2009	0.0	0.0	0.1	7.1	7.2	1.0
2010	0.0	0.0	0.9	8.5	9.4	2.1
2011	0.0	0.0	1.7	9.2	10.9	3.1
2012	0.0	0.0	2.5	9.8	12.3	3.9
2013	0.0	0.0	3.4	9.8	13.2	4.6
2014	0.0	0.0	4.2	10.3	14.5	5.4
2015	0.0	0.0	4.9	12.1	17.0	6.6
2016	0.0	0.0	5.6	13.5	19.1	7.7
2017	0.0	0.0	5.6	14.7	20.3	8.1
2018	0.0	0.0	5.5	15.3	20.8	8.3
2019	0.0	0.0	4.7	15.7	20.5	7.7
2020	0.0	0.0	3.9	17.7	21.6	7.5
Total	0.0	0.0	92.4	178.8	271.3	110.7

Option 3 closes the loophole discussed in Section V; namely, that under Option 2 a U.S. 14 CFR part 121 carrier could still purchase used aircraft in the future from a foreign carrier (that is not subject to 16g requirements). Thus, Option 2 does not provide 100% certainty that the part 121 fleet will be all 16g. An all 16g/partial-16g part 121 fleet (less the exemptions for commuter carriers) is ensured under Option 3 which requires at least partial 16g compliance by 2007.

[34] As noted elsewhere in this report, the figures above refer to serious injuries only. The *Cherry Benefits Analysis* of serious injuries reflects the net effect of two factors: 1) the decrease in injuries that results from improvement passenger protection, and 2) the *increase* in injuries that results from averting fatalities. The second factor follows from the Cherry methodology—16g impact survivors (who would have otherwise been killed by impact in a 9g seat) could: 1) perish due to a subsequent post-crash fire, 2) become seriously injured in a post-crash fire, or 3) survive unharmed by either the impact or a post-crash fire.

Table VI.4: Value of Lifecycle Casualties Averted By Year of Seat Installation
Option 3 Relative to Option 1 (Voluntary Industry Action)
($2.7 million per fatality, $0.5 million per serious injury, 7.0% discount rate, 2000 base year)

Seats Installed in Year…	Fatalities Averted	Injuries Averted	Undiscounted Dollars	Discounted Dollars
2000	5.1	5.9	$16.7	$12.5
2001	5.1	5.9	$16.6	$11.6
2002	5.0	5.8	$16.3	$10.7
2003	4.9	5.7	$16.1	$9.9
2004	4.9	5.7	$16.0	$9.1
2005	6.2	7.2	$20.4	$10.9
2006	6.0	7.0	$19.7	$9.8
2007	0.8	0.9	$2.5	$1.1
2008	0.7	0.9	$2.4	$1.0
2009	0.9	1.0	$2.9	$1.2
2010	1.8	2.1	$6.0	$2.3
2011	2.6	3.1	$8.6	$3.1
2012	3.4	3.9	$11.1	$3.7
2013	3.9	4.6	$13.0	$4.0
2014	4.6	5.4	$15.1	$4.4
2015	5.7	6.6	$18.6	$5.0
2016	6.6	7.7	$21.7	$5.5
2017	7.0	8.1	$22.9	$5.4
2018	7.1	8.3	$23.3	$5.2
2019	6.6	7.7	$21.7	$4.5
2020	6.5	7.5	$21.3	$4.1
Total	95.3	110.7	$312.6	$125.1

D. Factor 4: Net Costs

1. Passenger Seats

Option 3 would increase costs (over the baseline) in two ways: 1) additional full 16g and partial 16g certification programs would have to be implemented for newly manufactured and in-service airplanes, 2) seats in in-service airplanes would have to be replaced earlier (relative to the baseline). Table VI.5 shows incremental seat certification costs broken out by year.

Table VI.5: Incremental Passenger Seat Certification Costs Under Option 3
(Millions of undiscounted and discounted dollars, base year 2000)

	Undiscounted Costs	Discounted Costs
2000	$10.0	$10.0
2001	$10.0	$9.3
2002	$9.8	$8.6
2003	$9.8	$8.0
2004	$9.8	$7.4
2005	$12.5	$8.9
2006	$12.2	$8.1
2007	$1.6	$1.0
2008	$1.6	$0.9
2009	$1.9	$1.1
2010	$3.9	$2.0
2011	$5.5	$2.6
2012	$6.9	$3.1
2013	$8.0	$3.3
2014	$9.4	$3.6
2015	$11.5	$4.2
2016	$13.4	$4.6
2017	$14.2	$4.5
2018	$14.5	$4.3
2019	$13.5	$3.7
2020	$13.3	$3.4
Total	$193.3	$102.7

Seat cost and other costs associated with early replacement. Seat replacement and installation costs arise because Option 3 requires retrofit within a prescribed period. Thus, under this option, many passenger seats would be replaced earlier than operators would voluntarily chose. Table VI.6 shows incremental seat replacement and installation costs. Since virtually all seats would be retrofitted in seven years (by 2007), and given the seat life distribution assumption discussed in Section II, the analysis predicts a period after 2007 during which incremental costs are negative.

Table VI.6: Incremental Passenger Seat Replacement and Installation Costs Under Option 3 (Millions of undiscounted and discounted dollars, 2000 base year.)

	Seat Cost		Installation Cost		Total Cost	
	Undiscounted	**Discounted**	**Undiscounted**	**Discounted**	**Undiscounted**	**Discounted**
2000	$98.0	$98.0	$3.7	$3.7	$101.7	$101.7
2001	$91.3	$85.3	$3.5	$3.2	$94.7	$88.5
2002	$83.6	$73.0	$3.2	$2.8	$86.8	$75.8
2003	$78.8	$64.3	$3.0	$2.4	$81.8	$66.8
2004	$77.5	$59.2	$2.9	$2.2	$80.5	$61.4
2005	$77.4	$55.2	$2.9	$2.1	$80.3	$57.3
2006	$76.8	$51.2	$2.9	$1.9	$79.7	$53.1
2007	-$84.3	-$52.5	-$3.2	-$2.0	-$87.5	-$54.5
2008	-$88.5	-$51.5	-$3.4	-$2.0	-$91.9	-$53.5
2009	-$84.1	-$45.8	-$3.2	-$1.7	-$87.3	-$47.5
2010	-$61.0	-$31.0	-$2.3	-$1.2	-$63.3	-$32.2
2011	-$37.6	-$17.9	-$1.4	-$0.7	-$39.0	-$18.5
2012	-$17.6	-$7.8	-$0.7	-$0.3	-$18.3	-$8.1
2013	-$0.6	-$0.2	$0.0	$0.0	-$0.6	-$0.2
2014	$15.9	$6.2	$0.6	$0.2	$16.5	$6.4
2015	$34.0	$12.3	$1.3	$0.5	$35.3	$12.8
2016	$53.8	$18.2	$2.0	$0.7	$55.9	$18.9
2017	$58.9	$18.6	$2.2	$0.7	$61.1	$19.4
2018	$56.8	$16.8	$2.2	$0.6	$59.0	$17.5
2019	$37.2	$10.3	$1.4	$0.4	$38.6	$10.7
2020	$19.6	$5.1	$0.7	$0.2	$20.4	$5.3
Total	$486.0	$367.0	$18.4	$13.9	$504.4	$380.9

2. Flight Attendant Seat Costs

Incremental flight attendant seat costs would include: 1) increased certification costs, 2) seat retrofit costs (seat cost, installation, and early replacement), and 3) weight penalties.

Certification costs. According to industry representatives very few flight attendant seats are replaced before the aircraft is retired from passenger service (this analysis assumes that the replacement rate is 0). Therefore, two sources of certification costs are considered: 1) the increase in costs that occur because new airplane certification programs are shifted from 9g/partial 16g to full 16g, and 2) the increase in costs that results from the increasing number of certification programs (as a result of the retrofit requirement).

Flight attendant seat certification costs are computed as follows:

- Step 1: Determine the number of certification programs required for newly manufactured and in-service airplanes under this option.

- Step 2: Estimate the number of certification programs required for the forecast period under this option.
- Step 3: Estimate the cost of the certification programs under this option.
- Step 4: Subtract baseline (Option 1) costs from Option 3 costs to determine the incremental costs of Option 3.
- Step 5: Adjust Option 3 incremental costs for in-service airplanes only to account for cost savings resulting from modified flight attendant seat testing requirements. (possible adjustment to be included in future analyses—this assumption is *not* included in the current analysis).

This computation process is discussed elsewhere in this report, however, two items need additional clarification.

Projected number of certification programs. Incremental certification costs associated with newly manufactured airplanes are computed as before. Incremental costs for in-service airplanes, however, requires an assumption concerning the incremental number of certifications per year. This analysis assumes that the ratio of newly installed seats to seat certifications (derived in Section V) would apply to seats replaced under Option 3. For example, if in a given year 12 flight attendant seat certification programs were required for the approximately 500 flight attendant seats installed in newly manufactured airplanes operated under 14 CFR part 121; then approximately 44 seat certification programs would be required for the 1,900 seats retrofitted per year. This relationship is assumed to hold throughout the forecast period.

Tables VI.7 shows estimated flight attendant seat costs.

Table VI.7: Incremental Flight Attendant Seat Certification Costs Under Option 3
(Millions of undiscounted and discounted dollars, 2000 base year)

	Undiscounted	Discounted
2000	$10.2	$10.2
2001	$10.2	$9.5
2002	$10.2	$8.9
2003	$10.2	$8.3
2004	$10.2	$7.8
2005	$10.5	$7.5
2006	$10.4	$6.9
2007	$0.4	$0.2
2008	$0.4	$0.2
2009	$0.7	$0.4
2010	$2.2	$1.1
2011	$3.8	$1.8
2012	$5.3	$2.4
2013	$6.9	$2.9
2014	$8.5	$3.3
2015	$10.3	$3.7
2016	$12.0	$4.1
2017	$12.7	$4.0
2018	$13.0	$3.9
2019	$12.3	$3.4
2020	$11.7	$3.0
Total	$172.2	$93.5

Seat cost and installation. Seat procurement and installation costs are shown in Table VI.8. The estimates in Table VI.8, which include the assumption that no flight attendant seats would be voluntarily upgraded during the retrofit period, are based on the flight attendant seat cost and installation data discussed in Section III. *It is important to note that this analysis assumes that all non-full 16g seats would have to be replaced; that is, it is assumed that no installed non-full 16g seat would be able to demonstrate compliance.*

Weight penalty. Weight penalty estimates are derived as in Section V and are shown in Table VI.9. In this case, however, a larger population of flight attendant seats is affected (that is, both newly manufactured and retrofitted in-service seats). As in the analysis above, no attempt is made to account for differences in weight penalties between different types of seat installations or vintages of flight attendant seats.

Table VI.8: Incremental Flight Attendant Seat Installation Costs Under Option 3
(Millions of undiscounted and discounted dollars, 2000 base year)

	Seat Cost		Installation Cost		Total Replacement Cost	
	Undiscounted	**Discounted**	**Undiscounted**	**Discounted**	**Undiscounted**	**Discounted**
2000	$10.2	$10.2	$0.2	$0.2	$10.3	$10.3
2001	$10.2	$9.5	$0.2	$0.1	$10.3	$9.6
2002	$10.2	$8.9	$0.2	$0.1	$10.3	$9.0
2003	$10.2	$8.3	$0.2	$0.1	$10.3	$8.4
2004	$10.2	$7.8	$0.2	$0.1	$10.3	$7.9
2005	$10.2	$7.2	$0.2	$0.1	$10.3	$7.4
2006	$10.1	$6.7	$0.2	$0.1	$10.3	$6.9
2007	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2008	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2009	$0.3	$0.2	$0.0	$0.0	$0.3	$0.2
2010	$1.7	$0.9	$0.0	$0.0	$1.7	$0.9
2011	$3.2	$1.5	$0.1	$0.0	$3.3	$1.6
2012	$4.7	$2.1	$0.1	$0.0	$4.8	$2.1
2013	$6.3	$2.6	$0.1	$0.0	$6.4	$2.7
2014	$7.9	$3.1	$0.1	$0.0	$8.0	$3.1
2015	$9.6	$3.5	$0.2	$0.1	$9.7	$3.5
2016	$11.2	$3.8	$0.2	$0.1	$11.4	$3.8
2017	$11.7	$3.7	$0.2	$0.1	$11.9	$3.8
2018	$12.0	$3.6	$0.2	$0.1	$12.2	$3.6
2019	$11.2	$3.1	$0.2	$0.0	$11.4	$3.2
2020	$10.5	$2.7	$0.2	$0.0	$10.7	$2.8
Total	$161.6	$89.3	$2.5	$1.4	$164.1	$90.7

Table VI.9: Lifecycle Flight Attendant Seat Weight Costs Under Option 3
By Year of Seat Installation
(Millions of undiscounted and discounted dollars, 2000 base year.)

	Undiscounted Weight Costs			**Discounted Weight Costs**		
Seat Installed in Year…	**New Installations**	**Replacement Installations**	**Total**	**New Installations**	**Replacement Installations**	**Total**
2000	$0.0	$0.3	$0.3	$0.0	$0.1	$0.1
2001	$0.0	$0.3	$0.3	$0.0	$0.1	$0.1
2002	$0.0	$0.3	$0.3	$0.0	$0.1	$0.1
2003	$0.0	$0.3	$0.3	$0.0	$0.1	$0.1
2004	$0.0	$0.3	$0.3	$0.0	$0.1	$0.1
2005	$0.1	$0.3	$0.4	$0.0	$0.1	$0.1
2006	$0.1	$0.3	$0.4	$0.0	$0.1	$0.1
2007	$0.1	$0.0	$0.1	$0.0	$0.0	$0.0
2008	$0.1	$0.0	$0.1	$0.0	$0.0	$0.0
2009	$0.2	$0.0	$0.2	$0.0	$0.0	$0.0
2010	$0.2	$0.0	$0.2	$0.0	$0.0	$0.0
2011	$0.2	$0.1	$0.3	$0.0	$0.0	$0.1
2012	$0.2	$0.1	$0.3	$0.0	$0.0	$0.1
2013	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2014	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2015	$0.2	$0.2	$0.5	$0.0	$0.0	$0.1
2016	$0.2	$0.3	$0.5	$0.0	$0.0	$0.1
2017	$0.3	$0.3	$0.5	$0.0	$0.0	$0.1
2018	$0.3	$0.3	$0.5	$0.0	$0.0	$0.1
2019	$0.3	$0.2	$0.5	$0.0	$0.0	$0.1
2020	$0.3	$0.2	$0.5	$0.0	$0.0	$0.0
Total	$3.2	$4.0	$7.2	$0.5	$1.2	$1.7

E. Benefit-Cost Comparison: Option 3

In total, Option 3 would avert approximately 95 fatalities and 111 serious injuries over the lifecycle of seats installed between 2000 and 2020. Assuming $2.7 million per fatality averted and $0.5 million per serious injury averted, this is equivalent to a benefit of $312.6 million, or $125.1 million at present value (2000 dollars). Option 3 is estimated to cost approximately $1041.3 million, or $669.5 million at present value (2000 base year). In undiscounted dollars, Option 3 would cost approximately $11 million per fatality averted. The discounted benefit-cost ratio of this option is approximately 0.19. Considering only passenger seats, the discounted benefit-cost ratio of this option is approximately 0.254.

VII. Analysis of Option 4

Option 4 would require that, after 2005, all newly manufactured transport category airplanes operating under 14 CFR part 121, comply with the requirements of 14 CFR part 25.562 (a), (b), and (c). In addition, this option would require that, after 2002, if a seat is replaced then it must be replaced with a seat that meets TSO-C127a (minus HIC).

A. Factor 1: Baseline Accident/Casualty Rates

As discussed above, this study assumes that the baseline fatality and serious injury rates for the period 2000-2020 will be 0.2868 and 0.0436 per million enplanements, respectively. (See Section II.)

B. Factor 2: Future Distribution of Seat Types

The impact of this requirement on the distribution of seats is shown in Figure VII.1 and Table VII.1. All seats would be certificated as at least partial 16g by 2020; all seats would be certificated as full 16g within 50 years.

This factor does not take into consideration the possible disincentive effects that could be associated with Option 4. For example, if the costs of installing or certificating partial 16g seats are high, then some operators may delay seat replacement (that is, the mean time to seat replacement (MTSR) under Option 4 may be greater than the baseline MTSR). The affect of a MTSR shift is estimated to be roughly neutral with respect to benefit-cost.

It should be emphasized that the loophole discussed in Section V (14 CFR part 121 carriers purchasing used non-full-16g airplanes from foreign operators) is ***not*** *closed by the this option.*

C. Factor 3: Performance of full 16g, and partial 16g seats

Following the process outlined in Section II, the number of fatalities and injuries can be estimated under the assumption that Option 4 is implemented. The results are shown in Tables VII.2 (fatalities) and VII.3 (injuries).

The results can then be compared with the baseline fatality and injury results (see Tables II.13 and II.14). The difference between Option 4 results and baseline results gives an estimate of the number of fatalities and injuries averted due to full 16g seats. The estimates of casualties averted is then multiplied by the standard values for fatalities and serious injuries ($2.7 million and $0.5 million, respectively) to obtain dollar-denominated benefits estimates. The results are shown in Table VII.4).

Table VII.1: Projected Distribution of Seat Types Under Option 4

	Group I	Group II	Group III	Group IV	Group V
1999	272,720	205,271	178,598	36,534	22,960
2000	235,773	242,218	178,852	50,512	34,143
2001	194,919	283,072	179,154	67,114	47,424
2002	154,523	323,304	179,483	85,209	61,900
2003	115,007	362,820	179,857	105,771	78,349
2004	77,682	400,025	180,218	125,642	94,246
2005	46,440	393,965	168,522	174,588	140,434
2006	26,910	378,111	154,943	223,551	181,503
2007	13,760	357,933	138,972	272,746	228,023
2008	4,650	334,852	119,155	324,384	276,269
2009	0	309,067	99,310	373,494	327,892
2010	0	276,601	79,438	419,591	388,404
2011	0	238,416	64,284	462,535	452,496
2012	0	198,694	51,775	504,312	519,124
2013	0	161,593	40,426	546,632	584,019
2014	0	124,361	29,568	589,857	650,359
2015	0	81,009	934	651,329	725,185
2016	0	35,099	630	684,192	805,814
2017	0	0	275	705,258	890,584
2018	0	0	0	694,114	975,631
2019	0	0	0	687,218	1,059,552
2020	0	0	0	674,731	1,152,618

Figure VII.1: Option 4 Full Compliance with 14 CFR §25.562 After 2005
For Newly Manufactured Transport Category Airplanes Operating Under Part 121 Plus
Discretionary Replacement (TSO-C127a Without HIC) After 2007

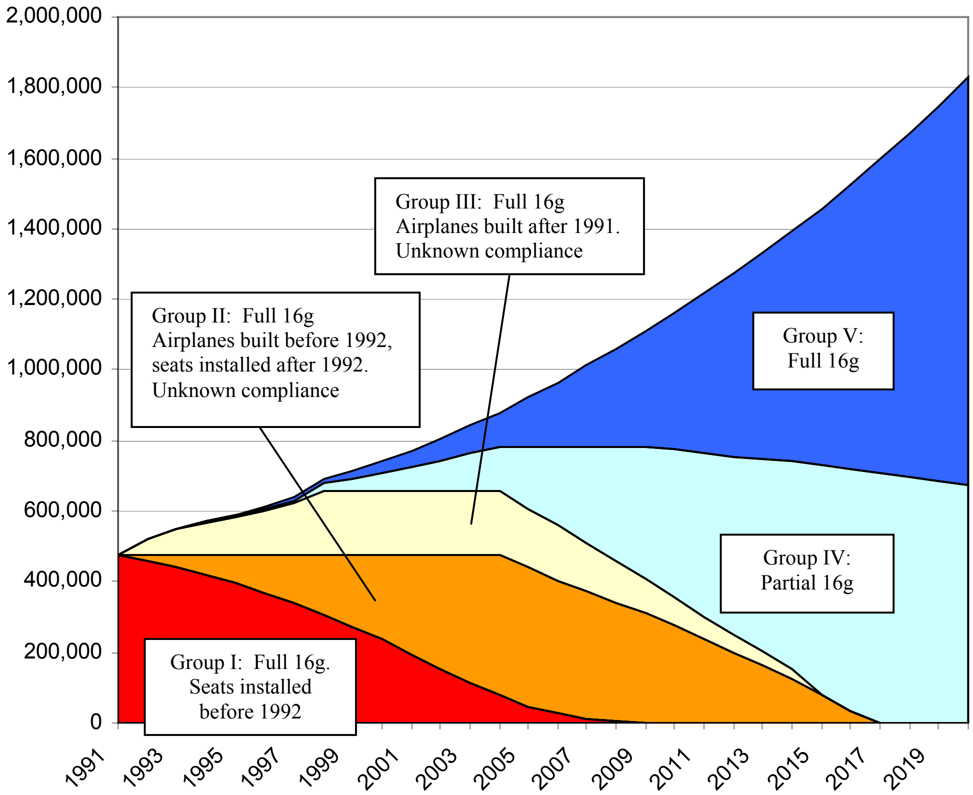


Table VII.2: Projected Lifecycle Fatalities Averted Under Option 4
By Year of Seat Installation

	Fatalities Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	**Group II**	**Group III**	**Group IV**	**Group V**	**Total**	**Relative to Option 1**
2000	0.4	0.1	0.6	1.5	2.5	0.0
2001	0.5	0.1	0.7	1.7	3.0	0.0
2002	0.5	0.2	0.8	1.9	3.3	0.0
2003	0.5	0.3	0.9	2.2	3.7	0.0
2004	0.4	0.3	0.8	2.1	3.7	0.0
2005	0.0	0.0	2.8	5.3	8.1	3.6
2006	0.0	0.0	2.8	4.7	7.6	3.4
2007	0.0	0.0	2.8	5.4	8.2	3.6
2008	0.0	0.0	3.0	5.6	8.5	3.7
2009	0.0	0.0	2.9	6.1	9.0	3.7
2010	0.0	0.0	2.8	7.3	10.1	3.9
2011	0.0	0.0	2.7	7.9	10.6	3.9
2012	0.0	0.0	2.8	8.4	11.2	4.0
2013	0.0	0.0	2.9	8.4	11.3	4.0
2014	0.0	0.0	3.1	8.8	11.9	4.1
2015	0.0	0.0	3.2	10.1	13.3	4.4
2016	0.0	0.0	3.3	11.0	14.3	4.5
2017	0.0	0.0	3.3	11.8	15.1	4.6
2018	0.0	0.0	3.4	12.0	15.4	4.6
2019	0.0	0.0	3.6	12.1	15.6	4.6
2020	0.0	0.0	3.7	13.3	17.0	4.9
Total	2.3	0.9	52.7	147.7	203.6	65.4

Table VII.3: Projected Lifecycle Serious Injuries Averted Under Option 4
By Year of Seat Installation

	Serous Injuries Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	Group II	Group III	Group IV	Group V	Total	Relative to Option 1
2000	0.5	0.1	0.7	1.7	2.9	0.0
2001	0.5	0.1	0.8	2.0	3.5	0.0
2002	0.5	0.2	0.9	2.2	3.8	0.0
2003	0.5	0.3	1.0	2.5	4.4	0.0
2004	0.5	0.4	1.0	2.4	4.3	0.0
2005	0.0	0.0	3.3	6.2	9.5	4.2
2006	0.0	0.0	3.3	5.5	8.8	4.0
2007	0.0	0.0	3.3	6.2	9.5	4.2
2008	0.0	0.0	3.5	6.5	9.9	4.3
2009	0.0	0.0	3.4	7.1	10.5	4.3
2010	0.0	0.0	3.3	8.5	11.7	4.5
2011	0.0	0.0	3.2	9.2	12.3	4.5
2012	0.0	0.0	3.2	9.8	13.0	4.6
2013	0.0	0.0	3.4	9.8	13.2	4.6
2014	0.0	0.0	3.6	10.3	13.8	4.7
2015	0.0	0.0	3.7	11.7	15.5	5.1
2016	0.0	0.0	3.8	12.8	16.6	5.3
2017	0.0	0.0	3.8	13.7	17.5	5.3
2018	0.0	0.0	4.0	13.9	17.9	5.4
2019	0.0	0.0	4.1	14.0	18.1	5.4
2020	0.0	0.0	4.3	15.5	19.8	5.7
Total	2.6	1.0	61.3	171.5	236.5	76.0

Table VII.4: Value of Casualties Averted By Year of Seat Installation
Option 4 Relative to Option 1 (Voluntary Industry Action)
($2.7 million per fatality, $0.5 million per serious injury, 7.0% discount rate, 2000 base year.)

Seats Installed in Year…	Fatalities Averted	Injuries Averted	Undiscounted Benefits	Discounted Benefits
2000	0.0	0.0	$0.0	$0.0
2001	0.0	0.0	$0.0	$0.0
2002	0.0	0.0	$0.0	$0.0
2003	0.0	0.0	$0.0	$0.0
2004	0.0	0.0	$0.0	$0.0
2005	3.6	4.2	$11.9	$6.3
2006	3.4	4.0	$11.2	$5.6
2007	3.6	4.2	$11.8	$5.5
2008	3.7	4.3	$12.2	$5.3
2009	3.7	4.3	$12.2	$5.0
2010	3.9	4.5	$12.7	$4.8
2011	3.9	4.5	$12.8	$4.6
2012	4.0	4.6	$13.0	$4.3
2013	4.0	4.6	$13.0	$4.0
2014	4.1	4.7	$13.4	$3.9
2015	4.4	5.1	$14.3	$3.9
2016	4.5	5.3	$14.8	$3.8
2017	4.6	5.3	$15.0	$3.6
2018	4.6	5.4	$15.1	$3.4
2019	4.6	5.4	$15.1	$3.1
2020	4.9	5.7	$16.0	$3.1
Total	65.4	76.0	$214.5	$70.2

D. Factor 4: Net Costs

1. Passenger Seats

Because Option 4 does not mandate a specific seat retrofit schedule, there are no incremental costs associated with premature seat replacement. However, costs for Option 4 are greater than Option 2 costs since a larger number of airplane model/variants would require certification testing.

Table VII.5 shows incremental seat certification costs broken out by type of installation (new versus replacement) and type of seat (full 16g, partial 16g and 9g) in undiscounted and discounted terms, respectively.

Table VII.5: Incremental Passenger Seat Certification Costs Under Option 4
(Millions of undiscounted and discounted dollars, 2000 base year.)

	Undiscounted Costs	Discounted Costs
2000	$0.0	$0.0
2001	$0.0	$0.0
2002	$0.0	$0.0
2003	$0.0	$0.0
2004	$0.0	$0.0
2005	$7.3	$5.2
2006	$6.9	$4.6
2007	$7.3	$4.6
2008	$7.6	$4.4
2009	$7.7	$4.2
2010	$8.0	$4.1
2011	$8.0	$3.8
2012	$8.1	$3.6
2013	$8.1	$3.4
2014	$8.3	$3.2
2015	$8.9	$3.2
2016	$9.2	$3.1
2017	$9.3	$2.9
2018	$9.4	$2.8
2019	$9.5	$2.6
2020	$10.1	$2.6
Total	$133.7	$58.3

2. Flight Attendant Seats

Broadly speaking, there are three ways to treat flight attendant seats under this option:

- Extend some type of discretionary replacement program to flight attendant seats. For example, require that, when they are replaced, flight attendant seats must meet a specified level of performance (dynamic loads and/or occupant injury criteria). Since flight attendant seats are typically not replaced, this would effectively mean that flight attendant seats would not be upgraded under this option.

- Require that, when passenger seats are replaced, then flight attendant seats must also be replaced.

- Do not impose any requirement on flight attendant seats.

This analysis assumes that flight attendant seats must be replaced when passenger seats are replaced. (*Again, it is important to note that this analysis does not take into consideration the possibility that Option 4 requirements could affect the average service life of passenger seats.*)

Under this assumption, flight attendant seat costs include: 1) increased certification costs, 2) seat retrofit costs (seat cost, installation cost, and early replacement), and 3) weight penalties.

Certification costs. Certification costs associated with flight attendant seat replacement are computed as in Section VI. In this case, however, replacement need not occur during a specified retrofit period. Table VII.6 shows incremental flight attendant seat certification costs in undiscounted and discounted dollars.

Following the procedure in Section VI, the number of certification programs required for flight attendant seat replacement is calculated using the ratio of new seat certifications to the number of new seats installed. Also, no adjustment is made to account for possible savings that would result from relaxing test standards that require representative walls and seat tracks.

Seat procurement, installation, and operating (weight) costs. Seat procurement and installation costs are shown in Table VII.7. Again, all non-full-16g seats are assumed to require replacement (i.e., existing seats would not be able to demonstrate compliance). Also, this analysis assumes that Option 4 requirements do not result in longer average seat lives. Weight penalty estimates are shown in Table VII.8.

Table VII.6: Flight Attendant Seat Certification Costs Under Option 4
(Millions of undiscounted and discounted dollars, 2000 base year.)

	Undiscounted Costs	Discounted Costs
2000	$3.2	$3.2
2001	$3.5	$3.3
2002	$3.9	$3.4
2003	$4.1	$3.4
2004	$4.2	$3.2
2005	$5.6	$4.0
2006	$5.6	$3.7
2007	$5.7	$3.5
2008	$5.9	$3.5
2009	$6.0	$3.3
2010	$6.1	$3.1
2011	$6.1	$2.9
2012	$6.4	$2.9
2013	$7.0	$2.9
2014	$7.5	$2.9
2015	$8.2	$3.0
2016	$8.6	$2.9
2017	$8.9	$2.8
2018	$9.3	$2.8
2019	$9.8	$2.7
2020	$10.3	$2.7
Total	$136.0	$65.9

Table VII.7: Flight Attendant Seat Installation Costs Under Option 4
(Millions of undiscounted and discounted dollars, 2000 base year.)

	Seat Cost		**Installation Cost**		**Total Replacement Cost**	
	Undiscounted	**Discounted**	**Undiscounted**	**Discounted**	**Undiscounted**	**Discounted**
2000	$4.0	$4.0	$0.1	$0.1	$4.1	$4.1
2001	$4.4	$4.1	$0.1	$0.1	$4.5	$4.2
2002	$4.9	$4.3	$0.1	$0.1	$5.0	$4.3
2003	$5.2	$4.2	$0.1	$0.1	$5.3	$4.3
2004	$5.3	$4.0	$0.1	$0.1	$5.4	$4.1
2005	$5.3	$3.8	$0.1	$0.1	$5.4	$3.8
2006	$5.3	$3.5	$0.1	$0.1	$5.4	$3.6
2007	$5.3	$3.3	$0.1	$0.1	$5.4	$3.4
2008	$5.6	$3.2	$0.1	$0.1	$5.7	$3.3
2009	$5.6	$3.0	$0.1	$0.0	$5.7	$3.1
2010	$5.6	$2.8	$0.1	$0.0	$5.7	$2.9
2011	$5.6	$2.7	$0.1	$0.0	$5.7	$2.7
2012	$5.8	$2.6	$0.1	$0.0	$5.9	$2.6
2013	$6.4	$2.6	$0.1	$0.0	$6.5	$2.7
2014	$6.9	$2.7	$0.1	$0.0	$7.0	$2.7
2015	$7.4	$2.7	$0.1	$0.0	$7.5	$2.7
2016	$7.8	$2.6	$0.1	$0.0	$7.9	$2.7
2017	$8.0	$2.5	$0.1	$0.0	$8.2	$2.6
2018	$8.4	$2.5	$0.1	$0.0	$8.6	$2.5
2019	$8.9	$2.5	$0.1	$0.0	$9.0	$2.5
2020	$9.3	$2.4	$0.1	$0.0	$9.5	$2.4
Total	$130.9	$66.2	$2.1	$1.0	$133.0	$67.2

Table VII.8: Flight Attendant Seat Weight Penalty Under Option 4
(Millions of undiscounted and discounted dollars, 2000 base year.)

	Undiscounted Weight Costs			Discounted Weight Costs		
Seat Installed in Year…	**New Installations**	**Replacement Installations**	**Total**	**New Installations**	**Replacement Installations**	**Total**
2000	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2001	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2002	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2003	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2004	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2005	$0.1	$0.1	$0.3	$0.0	$0.1	$0.1
2006	$0.1	$0.1	$0.3	$0.0	$0.1	$0.1
2007	$0.1	$0.2	$0.3	$0.0	$0.0	$0.1
2008	$0.1	$0.2	$0.3	$0.0	$0.0	$0.1
2009	$0.2	$0.2	$0.3	$0.0	$0.0	$0.1
2010	$0.2	$0.1	$0.3	$0.0	$0.0	$0.1
2011	$0.2	$0.1	$0.3	$0.0	$0.0	$0.1
2012	$0.2	$0.1	$0.3	$0.0	$0.0	$0.1
2013	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2014	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2015	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2016	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2017	$0.3	$0.2	$0.4	$0.0	$0.0	$0.1
2018	$0.3	$0.2	$0.4	$0.0	$0.0	$0.1
2019	$0.3	$0.2	$0.4	$0.0	$0.0	$0.1
2020	$0.3	$0.2	$0.5	$0.0	$0.0	$0.1
Total	$3.2	$2.6	$5.8	$0.5	$0.6	$1.0

E. Benefit-Cost Comparison: Option 4

Under the baseline assumptions, Option 4 would avert approximately 65.4 fatalities and 76.0 serious injuries over the lifecycle of seats installed during the period 2000-2020. Assuming $2.7 million per fatality averted and $0.5 million per serious injury averted, this is equivalent to a benefit of $214.5 million, or $70.2 million at present value (2000 dollars). Option 4 is estimated to cost approximately $408.6 million in undiscounted dollars, or $192.5 million at present value (2000 base year). In undiscounted dollars, Option 4 would cost approximately $6.25 million per fatality averted. The discounted benefit-cost ratio of this option is approximately 0.365. Considering only passenger seats, the discounted benefit-cost ratio of this option is approximately 1.179.

VIII. Analysis of Option 5

Option 5 would require that, after 2005, all newly manufactured transport category airplanes operating under 14 CFR part 121, comply with the requirements of 14 CFR part 25.562 (a), (b), and (c). In addition, this option would require that, after 2007~~2~~, if a seat is replaced then it must be replaced with a seat that meets TSO-C127a *including occupant injury criteria*.

A. Factor 1: Baseline Accident/Casualty Rates

As discussed above, this study assumes that the baseline fatality and serious injury rates for the period 2000-2020 will be 0.2868 and 0.0436 per million enplanements, respectively. (See Section II.)

B. Factor 2: Future Distribution of Seat Types

The impact of this requirement on the distribution of seats is shown in Figure VIII.1 and Table VIII.1. All seats would be certificated as 16g within 20 years.

This factor does not take into consideration the possible disincentive effects. For example, if the costs of installing or certificating partial 16g seats are high, then some operators may delay seat replacement (that is, the MTSR under Option 5 may be greater than the baseline MTSR). The affect of a MTSR shift is estimated to be roughly neutral with respect to benefit-cost.

*It should be emphasized that the loophole discussed in Section V (14 CFR part 121 carriers purchasing used non-full-16g airplanes from foreign operators) is **not** closed by the this option.*

C. Factor 3: Performance of full 16g, and partial 16g seats

Following the process outlined in Section II, the number of fatalities and injuries can be estimated under the assumption that Option 5 is implemented. The results are shown in Tables VIII.2 (fatalities) and VIII.3 (injuries).

The results can then be compared with the baseline fatality and injury results (see Tables II.~~1~~3 and II.~~1~~4). The difference between Option 5 results and baseline results gives an estimate of the number of fatalities and injuries averted due to full 16g seats. The estimates of casualties averted is then multiplied by the standard values for fatalities and serious injuries ($2.7 million and $0.5 million, respectively) to obtain dollar-denominated benefits estimates. The results are shown in Table VIII.4).

Table VIII.1: Projected Distribution of Seat Types Under Option 5, 2000-2020

	Group I	Group II	Group III	Group IV	Group V
1999	272,720	205,271	178,598	36,534	22,960
2000	235,773	242,218	178,852	50,512	34,143
2001	194,919	283,072	179,154	67,114	47,424
2002	154,523	323,304	179,483	85,209	61,900
2003	115,007	362,820	179,857	105,771	78,349
2004	77,682	400,025	180,218	125,642	94,246
2005	46,440	393,965	168,522	116,667	198,355
2006	26,910	378,111	154,943	107,693	297,361
2007	13,760	357,933	138,972	98,718	402,050
2008	4,650	334,852	119,155	89,744	510,909
2009	0	309,067	99,310	80,770	620,616
2010	0	276,601	79,438	71,795	736,200
2011	0	238,416	64,284	62,821	852,211
2012	0	198,694	51,775	53,846	969,589
2013	0	161,593	40,426	44,872	1,085,779
2014	0	124,361	29,568	35,898	1,204,319
2015	0	81,009	934	26,923	1,349,590
2016	0	35,099	630	17,949	1,472,057
2017	0	0	275	8,974	1,586,868
2018	0	0	0	0	1,669,745
2019	0	0	0	0	1,746,770
2020	0	0	0	0	1,827,348

Figure VIII.1: Option 5 Full Compliance with 14 CFR §25.562 After 2005 For Newly Manufactured Transport Category Airplanes Operating Under Part 121 Plus Discretionary Replacement (*TSO-C127a Including HIC*) After 2007

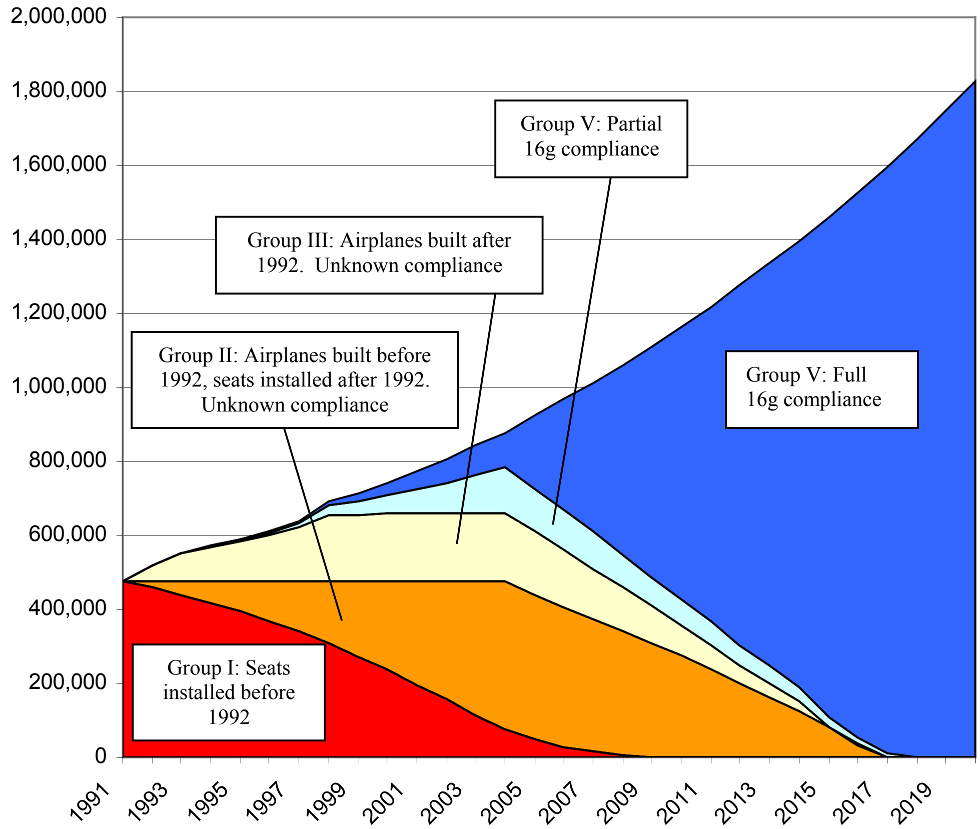


Table VIII.2: Projected Lifecycle Fatalities Under Option 5
By Year of Seat Installation

	Fatalities Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	**Group II**	**Group III**	**Group IV**	**Group V**	**Total**	**Relative to Option 1**
2000	0.4	0.1	0.6	1.5	2.5	0.0
2001	0.5	0.1	0.7	1.7	3.0	0.0
2002	0.5	0.2	0.8	1.9	3.3	0.0
2003	0.5	0.3	0.9	2.2	3.7	0.0
2004	0.4	0.3	0.8	2.1	3.7	0.0
2005	0.0	0.0	0.0	11.0	11.0	6.4
2006	0.0	0.0	0.0	10.4	10.4	6.2
2007	0.0	0.0	0.0	11.0	11.0	6.4
2008	0.0	0.0	0.0	11.5	11.5	6.7
2009	0.0	0.0	0.0	11.9	11.9	6.6
2010	0.0	0.0	0.0	12.9	12.9	6.7
2011	0.0	0.0	0.0	13.3	13.3	6.6
2012	0.0	0.0	0.0	13.9	13.9	6.7
2013	0.0	0.0	0.0	14.3	14.3	6.9
2014	0.0	0.0	0.0	15.0	15.0	7.1
2015	0.0	0.0	0.0	16.5	16.5	7.6
2016	0.0	0.0	0.0	17.6	17.6	7.8
2017	0.0	0.0	0.0	18.3	18.3	7.8
2018	0.0	0.0	0.0	18.8	18.8	8.0
2019	0.0	0.0	0.0	19.2	19.2	8.2
2020	0.0	0.0	0.0	20.7	20.7	8.5
Total	2.3	0.9	3.7	245.7	252.6	114.4

Table VIII.3: Projected Lifecycle Serious Injuries Under Option 5
By Year of Seat Installation

	Fatalities Averted Relative to Hypothetical 9g Fleet					
Seats Installed in Year…	Group II	Group III	Group IV	Group V	Total	Relative to Option 1
2000	0.5	0.1	0.7	1.7	2.9	0.0
2001	0.5	0.1	0.8	2.0	3.5	0.0
2002	0.5	0.2	0.9	2.2	3.8	0.0
2003	0.5	0.3	1.0	2.5	4.4	0.0
2004	0.5	0.4	1.0	2.4	4.3	0.0
2005	0.0	0.0	0.0	12.7	12.7	7.5
2006	0.0	0.0	0.0	12.1	12.1	7.3
2007	0.0	0.0	0.0	12.8	12.8	7.5
2008	0.0	0.0	0.0	13.4	13.4	7.8
2009	0.0	0.0	0.0	13.8	13.8	7.7
2010	0.0	0.0	0.0	15.0	15.0	7.8
2011	0.0	0.0	0.0	15.5	15.5	7.7
2012	0.0	0.0	0.0	16.2	16.2	7.8
2013	0.0	0.0	0.0	16.6	16.6	8.0
2014	0.0	0.0	0.0	17.4	17.4	8.3
2015	0.0	0.0	0.0	19.2	19.2	8.8
2016	0.0	0.0	0.0	20.5	20.5	9.1
2017	0.0	0.0	0.0	21.3	21.3	9.1
2018	0.0	0.0	0.0	21.9	21.9	9.3
2019	0.0	0.0	0.0	22.3	22.3	9.5
2020	0.0	0.0	0.0	24.0	24.0	9.9
Total	2.6	1.0	4.3	285.4	293.4	132.9

Table VIII.4: Value of Lifecycle Casualties Averted By Year of Seat Installation
Option 5 Relative to Option 1 (Voluntary Industry Action)
($2.7 million per fatality, $0.5 million per serious injury, 7.0% discount rate, 2000 base year.)

Seats Installed in Year…	Fatalities Averted	Injuries Averted	Undiscounted Dollars	Discounted Dollars
2000	0.0	0.0	$0.0	$0.0
2001	0.0	0.0	$0.0	$0.0
2002	0.0	0.0	$0.0	$0.0
2003	0.0	0.0	$0.0	$0.0
2004	0.0	0.0	$0.0	$0.0
2005	6.4	7.5	$21.1	$11.3
2006	6.2	7.3	$20.5	$10.2
2007	6.4	7.5	$21.1	$9.8
2008	6.7	7.8	$21.9	$9.6
2009	6.6	7.7	$21.7	$8.9
2010	6.7	7.8	$21.9	$8.3
2011	6.6	7.7	$21.7	$7.7
2012	6.7	7.8	$22.1	$7.4
2013	6.9	8.0	$22.6	$7.0
2014	7.1	8.3	$23.4	$6.8
2015	7.6	8.8	$24.9	$6.8
2016	7.8	9.1	$25.6	$6.5
2017	7.8	9.1	$25.7	$6.1
2018	8.0	9.3	$26.3	$5.8
2019	8.2	9.5	$26.8	$5.6
2020	8.5	9.9	$28.0	$5.4
Total	114.4	132.9	$375.3	$123.2

D. Factor 4: Net Costs

1. Passenger Seats

Because Option 5 does not mandate a specific seat retrofit schedule, there are no incremental costs associated with premature seat replacement. However, costs for Option 5 are greater than Option 2 costs since a larger number of airplane model/variants would require certification testing.

Tables VIII.5 shows incremental seat certification costs broken out by year of installation in undiscounted and discounted terms.

Table VIII.5: Incremental Passenger Seat Certification Costs Under Option 5
(Millions of undiscounted and discounted dollars 2000 base year.)

	Undiscounted Costs	Discounted Costs
2000	$0.0	$0.0
2001	$0.0	$0.0
2002	$0.0	$0.0
2003	$0.0	$0.0
2004	$0.0	$0.0
2005	$13.0	$9.3
2006	$12.6	$8.4
2007	$13.0	$8.1
2008	$13.7	$7.9
2009	$13.5	$7.4
2010	$13.7	$7.0
2011	$13.5	$6.4
2012	$13.7	$6.1
2013	$14.0	$5.8
2014	$14.5	$5.6
2015	$15.4	$5.6
2016	$15.8	$5.4
2017	$15.9	$5.0
2018	$16.3	$4.8
2019	$16.7	$4.6
2020	$17.5	$4.5
Total	$232.9	$101.9

2. Flight Attendant Seats

Similar to Option 4, there are three ways to treat flight attendant seats under Option 5:

- Extend some type of discretionary replacement program to flight attendant seats. For example, require that, when they are replaced, flight attendant seats must meet a specified level of performance (dynamic loads and/or occupant injury criteria).

- Require that, when passenger seats are replaced, then flight attendant seats must also be replaced.

- Do not impose any requirement on flight attendant seats.

This analysis assumes that flight attendant seats must be replaced when passenger seats are replaced. (*Again, it is important to note that this analysis does not take into consideration the possibility that Option 4 requirements could affect the average service life of passenger seats.*) Under this assumption, flight attendant seat costs include: 1) increased certification costs, 2) seat retrofit costs (seat cost, installation cost, and early replacement), and 3) weight penalties.

Certification costs. Certification costs associated with flight attendant seat replacement are computed as in Section VI. In this case, however, replacement need not occur during a specified retrofit period. Table~~s~~ VIII.6 shows incremental flight attendant seat certification costs in undiscounted and discounted dollars.

Following the procedure in Section VII, the number of certification programs required for flight attendant seat replacement is calculated using the ratio of new seat certifications to the number of new seats installed. Also, no adjustment is made to account for possible savings that would result from relaxing test standards that require representative walls and seat tracks.

Seat procurement, installation, and operating (weight) costs. Seat procurement and installation costs are shown in Table VIII.7. Again, all non-full-16g seats are assumed to require replacement (i.e., existing seats would not be able to demonstrate compliance). Also, this analysis assumes that Option 5 requirements do not result in longer average seat lives. Weight penalty estimates are shown in Table VIII.8.

Table VIII.6: Incremental Flight Attendant Seat Certification Costs Under Option 5
(Millions of undiscounted and discounted dollars 2000 base year.)

	Undiscounted Costs	Discounted Costs
2000	$3.2	$3.2
2001	$3.5	$3.3
2002	$3.9	$3.4
2003	$4.1	$3.4
2004	$4.2	$3.2
2005	$6.2	$4.4
2006	$6.2	$4.1
2007	$6.3	$3.9
2008	$6.6	$3.8
2009	$6.6	$3.6
2010	$6.7	$3.4
2011	$6.7	$3.2
2012	$7.0	$3.1
2013	$7.6	$3.1
2014	$8.2	$3.2
2015	$8.8	$3.2
2016	$9.3	$3.1
2017	$9.6	$3.0
2018	$10.1	$3.0
2019	$10.6	$2.9
2020	$11.1	$2.9
Total	$146.5	$70.5

Table VIII.7: Incremental Flight Attendant Seat Installation Costs Under Option 5
(Millions of undiscounted and discounted dollars 2000 base year.)

	Seat Cost		**Installation Cost**		**Total Cost**	
	Undiscounted	**Discounted**	**Undiscounted**	**Discounted**	**Undiscounted**	**Discounted**
2000	$4.0	$4.0	$0.1	$0.1	$4.1	$4.1
2001	$4.4	$4.1	$0.1	$0.1	$4.5	$4.2
2002	$4.9	$4.3	$0.1	$0.1	$5.0	$4.3
2003	$5.2	$4.2	$0.1	$0.1	$5.3	$4.3
2004	$5.3	$4.0	$0.1	$0.1	$5.4	$4.1
2005	$5.3	$3.8	$0.1	$0.1	$5.4	$3.8
2006	$5.3	$3.5	$0.1	$0.1	$5.4	$3.6
2007	$5.3	$3.3	$0.1	$0.1	$5.4	$3.4
2008	$5.6	$3.2	$0.1	$0.1	$5.7	$3.3
2009	$5.6	$3.0	$0.1	$0.0	$5.7	$3.1
2010	$5.6	$2.8	$0.1	$0.0	$5.7	$2.9
2011	$5.6	$2.7	$0.1	$0.0	$5.7	$2.7
2012	$5.8	$2.6	$0.1	$0.0	$5.9	$2.6
2013	$6.4	$2.6	$0.1	$0.0	$6.5	$2.7
2014	$6.9	$2.7	$0.1	$0.0	$7.0	$2.7
2015	$7.4	$2.7	$0.1	$0.0	$7.5	$2.7
2016	$7.8	$2.6	$0.1	$0.0	$7.9	$2.7
2017	$8.0	$2.5	$0.1	$0.0	$8.2	$2.6
2018	$8.4	$2.5	$0.1	$0.0	$8.6	$2.5
2019	$8.9	$2.5	$0.1	$0.0	$9.0	$2.5
2020	$9.3	$2.4	$0.1	$0.0	$9.5	$2.4
Total	$130.9	$66.2	$2.1	$1.0	$133.0	$67.2

Table VIII.8: Lifecycle Flight Attendant Seat Weight Penalty Under Option 5
By Year of Seat Installation
(Millions of undiscounted and discounted dollars 2000 base year.)

	Undiscounted Weight Costs			Discounted Weight Costs		
Seats Installed in Year…	**New Installations**	**Replacement Installations**	**Total**	**New Installations**	**Replacement Installations**	**Total**
2000	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2001	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2002	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2003	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2004	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2005	$0.1	$0.1	$0.3	$0.0	$0.1	$0.1
2006	$0.1	$0.1	$0.3	$0.0	$0.1	$0.1
2007	$0.1	$0.2	$0.3	$0.0	$0.0	$0.1
2008	$0.1	$0.2	$0.3	$0.0	$0.0	$0.1
2009	$0.2	$0.2	$0.3	$0.0	$0.0	$0.1
2010	$0.2	$0.2	$0.3	$0.0	$0.0	$0.1
2011	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2012	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2013	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2014	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2015	$0.2	$0.2	$0.4	$0.0	$0.0	$0.1
2016	$0.2	$0.2	$0.5	$0.0	$0.0	$0.1
2017	$0.3	$0.2	$0.5	$0.0	$0.0	$0.1
2018	$0.3	$0.2	$0.5	$0.0	$0.0	$0.1
2019	$0.3	$0.3	$0.5	$0.0	$0.0	$0.1
2020	$0.3	$0.3	$0.5	$0.0	$0.0	$0.1
Total	$3.2	$3.0	$6.3	$0.5	$0.7	$1.1

E. Benefit-Cost Comparison: Option 5

Under the baseline assumptions, Option 5 would avert approximately 114.4 fatalities and 132.9 serious injuries over the lifecycle of seats installed during period 2000-2020. Assuming $2.7 million per fatality averted and $0.5 million per serious injury averted, this is equivalent to a benefit of $375.3 million, or $123.2 million at present value (2000 dollars). Option 5 is estimated to cost approximately $518.6 million in undiscounted dollars, or $240.8 million at present value (2000 base year). In undiscounted dollars, Option 5 would cost approximately $4.53 million per fatality averted. The discounted benefit-cost ratio of this option is approximately 0.512. Considering only passenger seats, the discounted benefit-cost ratio of this option is approximately 1.185.

IX. Discussion of Assumptions

A. Factor 2: Future Distribution of Seat Types

There are several reasons why the baseline seat distribution forecast may be incorrect. We do not make any attempt to quantify the impact of alternative distribution assumptions, but qualitative discuss their implications.

1. New Type Certificates or New Derivatives

The baseline assumes that the current proportion of full 16g seats is relatively constant during the forecast period. However, since the adoption of Amendment 25-64, at least 3 aircraft models have been certificated to the full 16g standard. In addition, numerous derivative models have been certificated to a partial 16g standard. It is plausible, then, that the share of full 16g and certificated partial 16g seats will increase in the future.

In the absence of numerical simulations, a good approximation is that changes in this assumption are approximately neutral with respect to benefit-cost. This follows since an increase in the number of certificated 16g airplanes means a decrease in both costs (fewer "bad" airplanes to upgrade) and benefits.

2. Accelerated Retirement of Older Airplanes

Following previous regulatory evaluation work, this study assumes that passenger airplanes have a 42-year service. A shorter average service life would imply earlier replacement with newer aircraft.

3. Reversion to 9g Seats

This analysis assumes relatively low safety benefits associated with seats in Group I, II and III (see baseline Figure 2). This follows since there is considerable uncertainty over future economic conditions and industry intentions (if there is no perceived threat of a 16g retrofit rule). If, in the future, operators install (uncertificated) partial 16g replacement seats—that is, seats that have partial 16g performance, but are not certificated/tested—then the benefits will be small (seat performance is essentially the same) while costs would be high (primarily the costs of testing/certificating the seats).

4. Rulemaking Could Affect Seat Distribution

Potential rulemaking could also affect seat replacement. As noted earlier, a discretionary compliance rule could encourage some operators to avoid certification costs by delaying or foregoing seat replacement. While this assumption is approximately neutral with respect to benefit-cost since benefits, as well as costs, would be avoided if seat replacement is postponed, it would mean that the flying public would be exposed to greater risks than assumed in this report.

B. Factor 4: Net Costs

1. Airplane Modification Costs

This analysis does not consider possible costs associated with airplane modifications required to achieve 16g (or partial 16g) compliance. Industry representatives indicated that some modifications might be necessary for some airplane types. AIR believes that these costs would be small.

It is difficult to quantify the effect of this assumption because it depends on the particulars of rule implementation. For example, exceptions/exemptions have been granted for several certificated 16g and partial 16g airplanes (e.g. exemptions from head injury criteria for front row passenger seats). The magnitude of modification costs depend on the degree to which the FAA will grant exemptions

2. Number of Certification Programs Required

The number of certification programs required (and, hence, total certification costs), may be much lower than estimated in this analysis. This follows for three reasons (all related to the fact that industry will likely modify its behavior in response to a rulemaking).

- *Operators may economize on seat costs by delaying seat replacement*. This analysis assumes that the current pattern of seat replacement (mean seat replacement period of 14 years), is unchanged after the adoption of a rule. However, it is plausible that some operators will choose to reduce costs by delaying seat replacement.

- R*ecurring certification program costs may be lower than assumed in this analysis*. This analysis makes the assumption that whenever an airplane's seats are replaced a new certification program is required. Costs could be much lower if industry adopts practices that would (after an initial certification program for a new delivery) incur lower certification costs for subsequent seat replacements.

- *Possible standardization of seat classes or families*. It is possible that, given the high cost of certification, the industry will develop classes or families of seats that will lower the average cost of a new certification or reduce the number of certification programs needed.

3. Flight Attendant Seat Costs

This analysis makes two assumptions concerning flight attendant seats: 1) testing for seats installed in newly manufactured airplanes will be the same as testing for seats in retrofit installations, and 2) all "non-full-16g" seats in the fleet will be replaced. Based on industry information, however, it is possible that incremental seat testing costs could be reduced by one order of magnitude if walls and seat tracks are not included in the testing requirement for flight attendant seats.

C. Total Seat Replacement Costs

The potential impact of various options on airline/operator behavior can be better understood in the context of total seat replacement costs. Table IX.2 shows the various costs associated with seat retrofit for a notional airplane with 106 passenger seats and 3 flight attendant seats (single class).

Table IX.1: Summary of Seat Replacement Costs For a Notional Passenger Airplane

	Passenger Seat Costs	Flight Attendant Seat Costs
Certification Costs	Average seat certification cost ranges from negligible (if demonstrated through similarity) to $500,000 for premium class seat certification. Analysis assumes average cost is approximately $30~~25~~0,000. However, these costs may be amortized over aircraft with the same installations. Analysis assumes one passenger seat certification per ~1200 seats. Therefore, estimated cost for this notional airplane is about $300,000 ÷ 12 = **$25,000.**	Costs are negligible ($1,000) if demonstrated through similarity, if testing does not include walls, and if replacement TSO-127 seats can be installed. If TSO-127 seat design does not exist for this aircraft, then full design and certification costs must be included. $40,000-$60,000 for testing full 16g (if non-recurring design costs not required). $253,500 including nonrecurring costs for full 16g testing. Unknown cost if walls/seat tracks must be included (e.g., if representative wall cannot be found b/c manufacturer no longer exists). Again, costs may be amortized across similar airplanes. Analysis assumes one certification per 40 flight attendant seats. Assuming average certification is $250,000, then cost for this notional airplane is: $250,000 ÷ 13.3 = **$18,796**
Seat Procurement/ Installation	106 seats. $65/seat installation $1,714/seat average cost **$188,574** Total	$85/seat installation $5,400/seat average cost **$16,455** Total
Weight	Negligible	~$13 per seat per year or $39 per year.

INSERT AT THE END OF SECTION "IV. SUMMARY OF COSTS AND BENEFITS."

It is important to note that the cost and benefit estimates for option 5 (shown in tables 5, 6, and 7) differ slightly from the estimates presented in the November 2000 16g study. The November 2000 study assumed that the introduction of a new requirement would have little or no effect on the frequency of seat replacements or aircraft procurement or retirement rates, and predicted that all non-16g seats would be out of service by 2018. (This is a conservative assumption. Even if operators postponed seat replacement, the effect would be roughly equi-proportional for both costs and benefits, and, hence, neutral with respect to the discounted benefit-cost ratio.)

In practice, however, there are two problems with a discretionary seat replacement requirement. First, such a requirement would not cover aircraft that are purchased from non-part 121 carriers (for example, part 129 operators) until their seats were replaced. Second, it is conceivable that some operators would choose to circumvent the intent of the rule by replacing seats on a piecemeal basis. As a result, although the FAA expects that economic and marketing forces would compel the vast majority of operators to convert to 16g seats in the forecasted timeframe, a small number of non-16g seats could continue to be used in part 121 aircraft indefinitely.

To close these loopholes, the FAA is proposing a compliance deadline of 10 years after the date at which the "discretionary replacement" requirements of the proposed rule go into effect (approximately 14 years after the date of the final rule). After that date, non-16g passenger and flight attendant seats will be prohibited in any aircraft operating under 14 CFR part 121.

Using the forecast model derived in the November 2000 16g study, the FAA generously estimates that approximately 3.5% of part 121 passenger and flight attendant seats will be non-16g at that time. The costs of the deadline, then, were estimated using a methodology similar to the November 2000 study by comparing the discounted stream of costs and benefits with and without a deadline. Under this approach, the deadline is estimated to add approximately $3.9 million to costs and $0.05 million to benefits, at present value.

REVISED TABLES (ONLY AFFECTS DISCOUNTED VALUES FOR OPTION 5)

Table 5: Projected Lifecycle Costs and Benefits, Passenger Seats
Millions of Undiscounted and Discounted Dollars
(Option 5 adjusted for 10 year deadline)

	Costs		**Benefits**		**B/C**
	Undisc.	**Discount**	**Undisc.**	**Discount**	**Discount**
Reg. Eval. (Hi)	$667.5	$424.4	NA	NA	NA
Reg. Eval. (Lo)	$667.5	$424.4	NA	NA	NA
Option 1	$0.0	$0.0	$0.0	$0.0	NA
Option 2	$70.7	$29.6	$109.8	$34.4	1.164
Option 3	$697.7	$483.6	$306.4	$122.6	0.254
Option 4	$133.7	$58.3	$210.2	$68.8	1.179
Option 5 (adj)	$232.9	$105.4	$367.8	$120.9	1.147

Table 6: Projected Lifecycle Costs and Benefits, Flight Attendant Seats
Millions of Undiscounted and Discounted Dollars
(Option 5 adjusted for 10 year deadline)

	Costs		Benefits		B/C
	Undisc.	Discount	Undisc.	Discount	Discount
Reg. Eval. (Hi)	$85.0	NA	NA	NA	NA
Reg. Eval. (Lo)	$85.0	NA	NA	NA	NA
Option 1	$0.0	$0.0	$0.0	$0.0	NA
Option 2	$12.0	$4.1	$2.2	$0.7	0.170
Option 3	$343.5	$185.9	$6.3	$2.5	0.013
Option 4	$274.9	$134.2	$4.3	$1.4	0.010
Option 5 (adj)	$285.7	$139.3	$7.5	$2.5	0.018

Table 7: Total Projected Lifecycle Costs and Benefits
Millions of Undiscounted and Discounted Dollars
(Option 5 adjusted for 10 year deadline)

	Costs		Benefits		B/C
	Then-Year	Discount	Then-Year	Discount	Discount
Reg. Eval. (Hi)	$752.6	$424.4	$1,230.0	$531.0	1.25
Reg. Eval. (Lo)	$752.6	$424.4	$679.0	$293.0	0.69
Option 1	$0.0	$0.0	$0.0	$0.0	NA
Option 2	$82.7	$33.7	$112.1	$35.1	1.042
Option 3	$1,041.3	$669.5	$312.6	$125.1	0.187
Option 4	$408.6	$192.5	$214.5	$70.2	0.365
Option 5	$518.6	$244.7	$375.3	$123.3	0.504